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# THE CARNEGIE INSTITUTION OF WASHINGTON

PUBLICATION 346

1927

PRESS OF
JUDD & DETWEILER, INC.
WASHINGTON, D. C.

# CONTRIBUTIONS TO PALAEONTOLOGY
## FROM THE CARNEGIE INSTITUTION OF WASHINGTON

# ADDITIONS TO THE PALAEONTOLOGY OF THE PACIFIC COAST AND GREAT BASIN REGIONS OF NORTH AMERICA

By
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AND H. L. MASON

Published by the Carnegie Instit tution of Washington
October, 1927

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## I

# STUDY OF THE SKULL OF A FOSSIL SPERM-WHALE FROM THE TEMBLOR MIOCENE OF SOUTHERN CALIFORNIA

By REMINGTON KELLOGG

With nine plates

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# STUDY OF THE SKULL OF A FOSSIL SPERM-WHALE FROM THE TEMBLOR MIOCENE OF SOUTHERN CALIFORNIA

By Remington Kellogg

Collections made by Charles Morrice near Bakersfield, California, attracted the writer's attention to the large and interesting vertebrate fauna of the Temblor formation, a considerable part of which is still undescribed. The necessity for making a careful study of the pelagic mammalian fauna of this formation has been recognized for some years and in 1924 the California Academy of Sciences inaugurated field work in this region. As a result of the excavations made on one of the Shark Tooth Hills under the direction of Dr. G. Dallas Hanna[1] and Mr. Morrice, a rather varied fauna has been made known. Among the pelagic mammals represented in this fauna are cetotheres, porpoises, a squalodont, a sperm-whale, several species of pinnipeds and the peculiar pelagic *Desmostylus*. With the exception of the sharks, which were described by Dr. David Starr Jordan,[2] very little attention has been paid to the pelagic vertebrate fauna. Dr. John C. Merriam[3] has discussed the fauna of the *Merychippus* zone at the upper limit of the Temblor formation in the Coalinga region and the position of this fauna in the mammalian sequence of western North America. A few years ago, the writer[4] described one of the large pinnipeds found in this formation. Several writers have called attention to the presence of bones of cetaceans in this formation, but neither figures nor descriptions of the specimens have been published.

From the number of young or embryo skulls represented among the fragments which were excavated in a narrow trench on one of the Shark Tooth Hills, one might infer that this region was a favorite calving place for the sperm-whales of this stage of the Miocene. The presence of a number of young whales in a relatively small area is not surprising for, less than a century ago, at the time of calving, whales were very numerous in suitable lagoons on the Pacific Coast of North America. In former years considerable numbers of sperm-whales

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[1] G. Dallas Hanna, Miocene Marine Vertebrates in Kern County, California, Science, n. s., vol. 61, No. 1568, 71–72, Jan. 16, 1925.

[2] David Starr Jordan, The Fossil Fishes of California: With Supplementary Notes on Other Species of Extinct Fishes, Univ. Calif. Pub., Bull. Dept. Geol., vol. 5, No. 7, 95–144, pls. 11–12, Apr. 1907; David Starr Jordan and Carl Hugh Beal, Supplementary Notes on Fossil Sharks, Univ. Calif. Pub., Bull. Dept. Geol., vol. 7, No. 11, 243–256, Apr. 25, 1913.

[3] John C. Merriam, Tertiary Vertebrate Faunas of the North Coalinga Region of California, Trans. Amer. Philos. Soc., n. s., vol. 22, pt. 3, 1–44, 1915.

[4] R. Kellogg, Pinnipeds from Miocene and Pleistocene Deposits of California, Univ. Calif. Pub., Bull. Dept. Geol. Sci., vol. 13, No. 4, 23–132, Apr. 14, 1922.

(*Physeter catodon*) and gray whales (*Rhachianectes glaucus*) resorted to the numerous lagoons and inlets of Lower California to breed and bring forth their young. They were especially abundant around Ballenas Bay. Living sperm-whales are occasionally stranded on the beach and it is possible that some of these fossil specimens may have perished in this manner. Some catastrophe, such as violent volcanic activity and fall of ash, as suggested by Dr. F. M. Anderson, caused the death of a large number of pelagic mammals and sharks at the time this horizon of the Temblor formation was deposited. The bones occur in a stratum not over 3 feet in thickness. A considerable portion of the skull of a young sperm-whale was found within 20 feet of that of the adult. This specimen is of considerable importance because the bones are disassociated and certain structures which are not visible on the adult skull can be studied.

The skull of this fossil sperm-whale is asymmetrical, that is, the top of the braincase has been modified in such way that the blow holes and the component bones on each side are unlike in shape and size. A comparison of fossil and living types of sperm-whale skulls shows that the development of the fat or spermaceti cushion was accompanied by corresponding changes in the mechanical construction of the skull. The top of the braincase has been depressed below its original level and a supracranial basin resulted from this depression. The huge size of this supracranial basin is a conspicuous feature of the skull of the living *Physeter catodon*. As in the skull of the living sperm-whale, there are no distinct sockets in the upper jaw for lodging the teeth and it is evident that they were held in the rudimentary alveolar groove by the gum. The brain of the Temblor physeteroid was rather small in proportion to the size of the skull.

### Aulophyseter morricei, new genus and species

*Type specimen*—Cat. No. 11230, Division of Vertebrate Palaeontology, United States National Museum. The type consists of a skull in a fair state of preservation. The supraorbital process of the left frontal and overlying maxilla, the left lachrymal and jugal, as well as the extremity of the rostrum are missing. Four enamel-crowned teeth and a right periotic were found near the specimen.

*Paratype*—Portions of the skull (Cat. No. 11313) of the young whale or embryo was found about 20 feet from that of the adult.

*Type locality*—The occurrence is as follows: Near latitude 35° 28′ North and longitude 119° 27′ West, about 6.5 miles northeast of Bakersfield, 4 miles east of the Kern River Oil Field and 0.5 mile north of Kern River, Kern County, California. Section 25, Township 28 South, Range 28 East, Caliente Quadrangle, United States Geological Survey.

*Horizon*—In a fairly coarse, light gray, firm sandstone of Anderson's Zone C,[1] the uppermost fossil horizon of the Temblor formation, on a hill west of Round Mountain, locally known as one of the Shark Tooth Hills. The type skull was found by Charles

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[1] F. M. Anderson, Neocene Deposits of Kern River, California, and the Temblor Basin, Proc. Calif. Acad. Sci., ser. 4, vol. 3, 99, 101–102, Nov. 9, 1911.

Morrice during the first week of April 1924, and the skull of the young animal was found early in June of the same year. The skull of the adult, which may be considered the type of the species, is remarkable for its completeness and preservation. No complete skeleton of any of the cetaceans known to occur in this formation has been discovered at this locality. Fragments of skulls, broken bones and vertebrae are very abundant. The bones are not beach worn, but many show indications of decay which preceded fossilization. Like the other specimens, with which it was associated, the skull of the young cetacean is incomplete. Anderson has already commented upon the remarkable assemblage of marine invertebrates and vertebrates which are found in this relatively limited area and has concluded that this region must have been considerably off-shore at the time of their burial. Helvitian, Middle Miocene

### SKULL OF ADULT

In respect to the relations of the component parts of the dorsal surface of the skull (pl. 1) the approach is directly toward the conditions existing in *Physeterula dubusii*, one of the four genera of physeteroid whales found in the "sable noir" in the Antwerp basin of Belgium. All the other described specimens of Miocene physeteroids, so far as can be judged from the illustrations furnished by several authors, exhibit affinities more or less remote with the Temblor skull. The similarities and differences observable between *Physeterula* and the other genera will be pointed out in the discussion of the construction of the Temblor skull. One distinguishing feature of the skull of *Aulophyseter morricei* is the presence of closely approximated, shallow alveolar grooves and the absence of any trace of distinct or vestigial alveoli for lodging the teeth in the upper jaw. The method of implantation of the teeth in the skull of *Physeterula dubusii* does not appear to be known and the figures[1] of the type skull show that the tooth-bearing portions of the maxillae are missing. At the same time it should be noted that the teeth of *Physeterula dubusii* are characterized in part by the absence of enamel and that the mandibular teeth are worn on the superior and posterior surfaces, from which it is inferred that teeth were present in the upper jaw. Some uncertainty as to the generic allocation of the skull from the Temblor formation may arise from the fact that the lower jaws are not known. Four teeth were found in the adjoining matrix which have well-developed enamel crowns. Unfortunately for the purposes of comparison a considerable portion of the type skull of *Physeterula dubusii* is missing. The relations of the component parts of the Belgian skull, as far as preserved, and the position of the maxillary foramina appear to correspond in most respects with the Temblor skull. Furthermore, the periotic of this Temblor physeteroid resembles very closely, except in size the two periotics found in the antwerp deposits which Abel[2] referred to *Eurhinodelphis longirostris*. These two periotics agree in all essential features with periotics of other physeteroids and differ from those of all other known toothed whales. Fortuitous circumstances no doubt resulted in their being associated with *Eurhinodelphis* material, either at the time of excavation or in the museum. The Temblor skull does not bear any generic resemblance to *Scaldicetus mortezelensis* of the Sarmatian stage of Belgium, but the above-mentioned periotics may belong to any one of the four types of Belgian physeteroid whales. A very similar periotic, but of smaller size, has been found in the Calvert Miocene formation of Maryland. It is the writer's opinion, based upon several years' study, that the periotic bone alone in the case of the Cetacea is sufficiently diagnostic to indicate relationship. In the present instance, no periotics were found associated with the skull in question—that of *Physeterula dubusii*—and the periotic which may belong to this species is labeled as having been found at another locality, but within the same formation. Hence any allocation must remain more or less provisional until another skull of *Physeterula dubusii* is found with at least one associated periotic. The Temblor specimens differ in many fundamental details from the skulls of most of the described genera of fossil physeteroids, but do exhibit a marked resemblance to that of *Physeterula dubusii*, and in a lesser degree to *Thalassocetus antwerpiensis*. Although the Temblor skull possesses many of the structural peculiarities of *Idiophyseter merriami*, the latter may be distinguished by the following features: The occurrence of 4 or more alveoli along the outer border of each maxilla; the presence of a sharply defined mesial longitudinal ridge formed by the maxillae and palatines; and the presence of a longitudinal ridge on the inner border of the apophysis of the maxilla and other peculiarities which suggest the type of maxilla present on a skull of a very young *Physeter catodon*.

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[1] O. Abel, Les Odontocètes du Bolderien (Miocène supérieur) d'Anvers, Mém. Mus. Roy. d'Hist. Nat. de Belgique, Bruxelles, tome 3, text-figs. 11, 12, 1905.

[2] O. Abel, Les Dauphins longirostres du Boldérien (Miocène supérieur) des environs d'Anvers, Mém. Mus. Roy. d'Hist. Nat. de Belgique, Bruxelles, tome 2, pl. 17, figs. 11, 12, 1902.

### DORSAL VIEW

This aspect (pl. 1) shows the general outlines of the skull, the relations of the component parts and the features wherein it appears to resemble *Physeterula dubusii*. The supraorbital process of the left frontal and the overlying maxilla, as well as the extremity of the rostrum are missing and have been restored to show the approximate appearance of the skull when complete.

As seen from a dorsal view, the broad, more or less flattened premaxillae form the dorsal surface of the median portion of the rostrum and shallow supracranial basin. The great width of the premaxilla is a characteristic peculiarity of this skull and also constitutes one of the more obvious features which distinguish the Temblor skull and that of *Physeterula dubusii* from those of *Diaphorocetus poucheti*[1] and *Scaldicetus mortezelensis*.[2] As in other physeteroids, the premaxillae are dissimilar in form. The upper surface of the right premaxilla is more or less flattened for a distance of 400 mm. in front of the antorbital notches. It passes backward upon the upper surface of the cranium and, posterior to the nasal passages, expands into a broad thin plate which is applied to the upper surface of the frontal, overlapping the maxilla along its internal margin. A rather large foramen pierces the right premaxilla at the level of the antorbital notches. The postnarial portion of the premaxilla may have been in contact with the nasal. The left premaxilla has been turned out of its course by the enlargement of the corresponding respiratory passage and apparently terminated near the posterior margin of this aperture as in *Physeter*. No foramen is present in the left premaxilla or at least the orifice does not appear on the dorsal surface. The inner margins of the premaxillae are in contact anteriorly and completely roof the mesorostral gutter. The inner border of the left premaxilla has been destroyed in front of the plug-like presphenoid for a distance of 245 mm., but the curvature of both premaxillae indicates that they were in contact over most of the length of the mesorostral gutter as in *Idiorophus patagonicus*.[3] Anterior to the widest part of the rostrum, the upper surfaces of both premaxillae commence to slope laterally and this twisting becomes more accentuated toward the extremity. In front of the anterior end of the vomer, the premaxillae meet ventrally in a linear suture and entirely enclose the mesorostral gutter. The premaxillae, by themselves, form the extremity of the rostrum. For a distance of approximately 550 mm. in front of the mesethmoid, the mesorostral gutter averages about 60 mm. in width, with the floor formed by the anterior extension of the vomer and the roof by the horizontal plates of the premaxillae. The vomer increases slightly in width posteriorly and gradually attains a higher position on the lateral walls.

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[1] F. P. Moreno, Noticias sobre algunos cetáceos fósiles y actuales de la República Argentina conservados en el Museo de La Plata, Revista del Museo de La Plata, tomo 3, pl. 10, 1892.

[2] O. Abel, Les Odontocètes du Bolderien (Miocène supérieur) d'Anvers, Mém. Mus. Roy. d'Hist. Nat. de Belgique, Bruxelles, tome 3, 67, fig. 5, 1905.

[3] R. Lydekker, Contributions to a Knowledge of the Fossil Vertebrates of Argentina. II: Cetaceans Skulls from Patagonia, Anales del Museo de La Plata, vol. 2, for 1893, 4–7, pl. 2, Apr. 1894; A. Cabrera, Cetáceos Fósiles del Museo de La Plata, Revista del Museo de La Plata, Buenos Aires, tomo 29, 406–408, fig. 18, 1926.

In *Diaphorocetus poucheti* the inner margins of the premaxillae were not in contact above the mesorostral gutter, while those on the type skull of *Orycterocetus mediatlanticus*[1] are so imperfectly preserved that one hesitates to offer any opinion. As regards width and general outlines, the premaxillae of the Temblor skull are of the same general type as those of *Idiophyseter merriami*.[2] On the Temblor skull the width of the right premaxilla at the level of the antorbital notch is considerably greater than the maxilla at the same level, that is, measuring from the external margin of the premaxilla to the antorbital notch. Turning to the skull of *Scaldicetus mortezelensis* attention may be directed to the fact that the width of the right premaxilla at the level of the antorbital notch is less than one half of the width of the incomplete strip of the right maxilla and is still narrower opposite the respiratory passages.

In another peculiarity the Temblor skull differs from that of *Scaldicetus mortezelensis* and this involves a more fundamental structural modification than some of those mentioned previously. The mesial side-to-side constriction of the rostrum of the Temblor skull is very noticeable, and in this feature it resembles *Orycterocetus mediatlanticus* and *Idiorophus patagonicus*. The distance from the anterior margin of the left respiratory passage to the posterior face of the left occipital condyle is slightly less than two-thirds of the distance from the anterior margin of the same respiratory passage to a point where the maxilla is no longer visible from a dorsal view. The extremities of both maxillae are missing on the skull of *Scaldicetus mortezelensis* but, at the same relative distance from the anterior margin of the left respiratory passage, each maxilla is at least as wide as the corresponding premaxilla. This indicates that the mesial side-to-side constriction of the rostrum is much less pronounced in *Scaldicetus mortezelensis* and possibly that it tapers gradually.

The maxillae are the most massive bones in the skull and contribute the major portion of the palatal surface of the rostrum. The right antorbital notch is deep and rather narrow. In front of this notch, the outer margin of the right maxilla is rounded off. Posterior to the antorbital notch, the maxilla becomes relatively thick and forms the lateral wall of the supracranial basin. The maxilla as a whole projects upward behind the antorbital notch and overrides the frontal, leaving a large portion of the supraorbital process exposed when the skull is viewed from above. The narrow apophysis of the maxilla conceals the lachrymal from a dorsal view. A thin process of the right maxilla which forms the roof above the maxillary incisure has been destroyed. Fortunately the right maxilla of the young skull (pl. 6, fig. 1) is essentially complete in this region and shows the normal relation of the large maxillary incisure to the smaller posterior maxillary foramen. The left maxilla of the young skull is damaged in the same manner as in the adult. The orifice of the posterior foramen looks upward and backward. Skulls of *Orycterocetus mediatlanticus* and *Idiorophus patagonicus* are characterized in part by the presence of a rather small maxillary incisure, as well as by anterior, inferior and superior maxillary foramina. These smaller foramina were not developed on the maxilla of the Temblor skull. There is a longitudinal depression on the dorsal surface of the right maxilla in front of the maxillary incisure, and the posterior maxillary foramen opens into a shallow concavity. In *Physeterula dubusii* the position and direction of the posterior maxillary foramen agrees fairly well with that in the young skull from the Temblor formation, but the maxilla does not appear to be hollowed out behind the orifice as in the adult Temblor skull.

The facial depression, in which the fat or spermaceti cushion rests, occupies a relatively large area on the dorsal surface of the skull. This supracranial basin is limited posteriorly by the transverse crest of the supraoccipital and is continued laterally to the elevated portions of the maxillae. It extends forward as far as the mesorostral gutter is accidentally exposed. The semi-circular wall which encloses this basin commences near the widest part of the rostrum and rises gradually, attaining its greatest elevation near the middle of the supraoccipital. Above the temporal fossa, the outer margin of the maxilla follows the corresponding border of the frontal and does not over-roll or project laterally beyond the latter. The postnarial portion of the right maxilla did not meet the opposite one in the middle line and the internal border is relatively thin. The left respiratory passage is formed by the mesethmoid and possibly the ectethmoid on the inner side, and by the premaxilla in front, on the outside and on the rear. Inferiorly, the vomer curves around the inside and back of each passage while the pterygoid and its hamular process contribute the remainder of the inferior border. A V-shaped portion of the upper end of the mesethmoid is missing and this defect gives the bone a rather unusual shape as shown on plate 1. The presphenoid is an irregular mass of bone which projects forward and contributes the plug-like process at the posterior end of the mesorostral gutter. The distortion resulting from the depression of the facial portion of the skull has not been confined to the respiratory passages, but has altered the lengths and relations of the premaxillae as noted above, although the maxillae and frontals were no doubt nearly symmetrical. The displacement of the presphenoid appears to be limited to two directions; laterally it slopes obliquely downward from left to right while its main axis forms an angle with the sagittal plane of the skull.

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[1] R. Kellogg, Additions to the Tertiary History of the Pelagic Mammals on the Pacific Coast of North America, Carnegie Inst. Wash. Pub. No. 348, 9–11, 13, pl. 4–5, Apr. 22, 1925.

[2] R. Kellogg, *op. cit.*, 19, text-fig. 1, pl. 1, fig. 1.

Some structural peculiarities are visible in the skull of the young Temblor physeteroid which supplement the description of the adult skull. Fortunately the supraorbital processes of the frontals are not ankylosed with the bones which comprise the rostrum and can be studied separately. Except for the loss of the nearly vertical plate-like portion of the frontal which meets its fellow along the middle line, the supraorbital process of the left frontal is essentially complete. Internally, the supraorbital process of the left frontal has fused with the orbitosphenoid and the exact limits of these two bones are not indicated by sutures. Hence the presphenoid, orbitosphenoid and the supraorbital process of the left frontal apparently represent one continuous bone. The supraorbital process of the left frontal thus appears to be continuous with the bones which contribute the posterior walls for the respiratory passages.

On the rostral face of the presphenoid, the mesethmoid occupies the same position as on the adult skull. The presphenoid and its lateral wings, or orbitosphenoids, resemble the corresponding portions of a young *Physeter* skull very closely. A brief description of this region in the skull of a very young *Physeter catodon* may make the following discussion a little clearer. In the young *Physeter* skull, the vertical plate-like portion of the frontal is very thin and is not fused with its fellow along the middle line. This plate is rather deep (240 mm.), extending from the presphenoid to the transverse crest formed by the supraoccipital. Posterior to the open channel for the optic nerve on the ventral face of the supraorbital process and between the base of this channel and the point where the optic nerve passes through the orbitosphenoid, a broad inferior process of the frontal is deeply mortised into the dorsal face of the alisphenoid and is held in position by grooves and ridges on the opposing surfaces. The optic nerve pierces the orbitosphenoid, although there is a fissure on the ventral face of that bone. The wing-like process of the presphenoid, or orbitosphenoid, is lodged in the deep groove on the ventral face of the frontal which is an internal continuation of the channel for the optic nerve. On the left side, there is a small foramen in the vertical plate of the presphenoid at the level of the upper margin of the mesethmoid which may afford passage for the nasal branch of the ophthalmic division of the trigeminal nerve. The right side of this foramen is incomplete. No orifices for olfactory nerves are present. The mesethmoid, which forms the most dorsal portion of the partition between the respiratory passages, arises on the rostral wall of the presphenoid. If the ectethmoids are present, they are already fused with the mesethmoid and presphenoid even at this early stage of growth.

Turning again to the skull of the young Temblor physeteroid (pl. 6, fig. 1), we find that the mesethmoid arises on the rostral wall of the presphenoid at the same level as in the young *Physeter* skull, and below it on each side there appears to be a small plate-like bone which in position corresponds with the ectethmoid in skulls of living toothed whales. Because of the present condition of the bones involved, the sutures defining the ectethmoids can not be traced with any degree of certainty and this interpretation is subject to future confirmation. A small foramen, 4 mm. in diameter, presumably for the nasal branch of the ophthalmic division of the trigeminal nerve, appears to have been present on the posterior wall of the right respiratory passage in a position corresponding to that in the young *Physeter* skull, for there is a notch at this point. No trace of this foramen can be found on the left side. The small triangular piece of the vertical plate-like portion of the presphenoid, which in the young *Physeter* skull separated the vertical plate-like portions of the frontals on the middle line at the base, is missing. Attention may be directed also to the presence of a rather large depression on the posterior wall of the left respiratory passage in the skull of the young Temblor physeteroid. This depression lodges the extremity of the left premaxilla. There are no orifices through which the olfactory nerves could pass. It is thus evident that the sense of smell was not retained by this Temblor physeteroid.

Careful search was made for small foramina in the posterior walls of the respiratory passages in the skull of the adult Temblor physeteroid which would afford passage for the nasal branches of the ophthalmic division of the trigeminal nerve, but none was found. A small pit is, however, present below the crest of the mesethmoid on the posterior wall of each respiratory passage. These pits, measuring about 27 mm. in diameter, may have resulted from imperfections in fossilization. In the skulls of the young and adult Temblor physeteroids, a ventral process of the frontal is mortised into the dorsal face of the alisphenoid in the same manner as in the young *Physeter catodon* skull.

While the differences in the shape, size and relations of the maxillary and premaxillary bones observed in the skulls of fossil and living toothed-whales may be explained by various factors connected with telescoping, the arrangement of the bones in the region of the respiratory passages appears to depend, in part at least, upon additional factors. The relations of the bones in the region of the respiratory passages as well as other asymmetrical conditions observed in skulls of physeteroids appear to have some relation to the depression of the facial portion of the braincase. In order to explain the origin of the arrangement of the bones in the region of the respiratory passages in skulls of physeteroids it appears necessary to consider the relations of these bones in other toothed whales. The position of the mesethmoid with reference to the frontals in certain well-known types of toothed whales is especially instructive and furnishes data from which one may visualize the steps which culminated in the conditions found in skulls of physeteroids. The transition from one stage to another can not be traced at present in a single phyletic series, and recourse must be had to several unrelated types of toothed whales. The brief review which follows is necessarily incomplete, but it seems likely that the structural modifications under discussion may represent successive stages in the closure of the foramina for the olfactory nerves and in the changes in the relations of the mesethmoid and ectethmoids.

In *Squalodon* and *Ceterhinops*, the mesethmoid forms the most dorsal portion of the partition between the respiratory passages, divides the opening between the frontals into two foramina through which the olfactory nerves pass and, extending upward, underlies the nasals and provides support for the vertex of the skull. The ectethmoids lie external to the foramina for the olfactory nerves and overspread the internal borders of the vertical plate-like portions of the frontals. On the skull of *Zarhachis*, each ectethmoid in the region of the crescentic orifice for the olfactory nerve is twisted almost at right angles to the main body of the bone. The curvature of the ectethmoid around the olfactory foramen is so unusual in appearance that one might view the semi-ovoidal rostral border as being the outer margin of the ectethmoid and that the border which incloses the foramen at the caudal end is the internal border. If this interpretation is correct, then the flattened condition of the ectethmoid in living porpoises is a later development and is indicative of one of the methods by which the closure of the olfactory foramina has been effected. On a young *Grampus* skull, the dorsal margins of the lateral plate-like ectethmoids do not meet the mesethmoid above the presphenoid as in an older individual and, above the level of the latter, there is a fissure which extends inward from the internal margin of each ectethmoid to the vestigial foramen for the olfactory nerve. The ectethmoid appears to have enveloped the foramen. In older individuals, this small foramen disappears and the ectethmoids extend upward to the nasals. In practically all of the living dolphins, a continuous sheet of bone, the cribriform plate of most mammals, covers the area through which the olfactory nerves originally found passage.

A more advanced stage in the shifting of the mesethmoid and ectethmoids appears to be present in skulls of physeteroids. In this family, the more or less vertical plate-like portions of the frontals overlap on the middle line and the mesethmoid has been depressed until it forms part of the plug-like process at posterior end of mesorostral gutter and inferiorly is applied to the vertical plate of the presphenoid. The mesethmoid has lost its relation with the frontals and is embraced by the trough of the vomer; the opening through which the olfactory nerves originally found passage has disappeared with the overlapping of the frontals on the midline.

From a dorsal view the frontals are almost completely hidden by the overlying maxillae and premaxillae. Since the nasal bone is missing the underlying frontal is exposed behind the left respiratory passage.

The zygomatic processes are placed relatively farther forward than in *Diaphorocetus poucheti*, with the anterior extremities extending forward below the postorbital projections of the supraorbital processes of the frontals. The lateral extensions of the exoccipitals curve forward giving the posterior outline of the skull, when viewed from above, a distinctly rounded appearance. In *Scaldicetus mortezelensis*, the posterior angles of the zygomatic processes project backward beyond the level of the exoccipitals and modify the contour of the occipital face of the skull.

### Posterior View

From an occipital view (pl. 4, fig. 1), the lower half of the skull is shown to be in a better state of preservation than the upper half. The upper margin of the supraoccipital had been weathered away before the skull was found and considerable portions of the original surfaces of the occipital condyles have been lost. The exoccipitals are rather large plate-like bones which project laterally and conceal the zygomatic processes from a posterior view. Laterally and anteriorly the exoccipitals are suturally united with the squamosals, inferiorly they are fused with the basioccipital, and superiorly they merge into the broad supraoccipital. The restoration of the left supraorbital process was not in place at the time this photograph was taken, which explains the more or less asymmetrical appearance of this view of the skull. Ventral to the condyles and internal to the exoccipitals are the falcate processes of the basioccipital, and further forward portions of the deep plates of the pterygoids and their hamular processes appear. A deep jugular incisure separates the internal margin of the exoccipital from the extremity of the falcate process of the basioccipital. The canal for the passage of the jugular vein and nerves is rather long, and as a result of an accident a portion of the canal is visible below the left condyle. The foramen magnum is relatively large and more or less ovoidal in outline. In their present condition, the occipital condyles are considerably broader near the apex than near the base, and slightly convex from side to side. They are borne on short condylar processes. The internal margins of the condyles are concave and converge inferiorly. In proportion to the size of the skull, the condyles of the Temblor specimen are considerably smaller than those of *Idiophyseter merriami*.

### LATERAL VIEW

Aside from the extremity of the rostrum, practically all of the structures visible from a lateral view (pl. 5, fig. 1) are preserved in their original condition. The rostrum is rather deep in comparison to *Idiophyseter merriami* and *Diaphorocetus poucheti;* the depth of the rostrum in front of the mesial constriction is slightly greater than one-third of the maximum depth of the braincase. Between the mesial constriction and the antorbital notch, the outer border of the maxilla is relatively thin, increasing in depth posteriorly and attaining its maximum thickness at the widest part of the rostrum. This thin outer edge of the maxilla disappears near the mesial constriction of the rostrum, and from this point forward the outer surface slopes obliquely downward and inward from the premaxillary suture. The extremity of the right maxilla is missing and the wide white line shown on plate 5, figure 1, indicates the broken anterior edge. Originally the extremity of the maxilla was continued some distance beyond this point and the position of the premaxillary suture is indicated by the narrow white line. The shallow alveolar groove is visible from a lateral view. Portions of the rostrum are missing on many of the previously described fossil physeteroid skulls and in the case of those on which the extremity is preserved it is formed by the premaxillae alone. Three of the teeth on each side of the rostrum are implanted in the premaxilla in *Idiorophus patagonicus* and *Ontocetus oxymycterus*.[1] On comparing the skulls of the several known genera of fossil physeteroids it was observed that the premaxillary portion of the rostrum was relatively short and co-extensive with not more than 3 alveoli. These observations were used as a basis for restoring the rostrum of the Temblor skull.

From the mesial constriction of the rostrum backward, the outer margin of the maxilla rises gradually and this condition has been brought about by the peculiar modifications which resulted in the depression of the frontal and overlying bones to form the supracranial basin. The angle which the suture between the maxilla and frontal above the orbit forms with the rostral axis is one of the characteristic peculiarities of most physeteroids. On this Temblor skull the slope of this suture is much more oblique than in *Idiorophus*, *Diaphorocetus* or *Idiophyseter*, and is at least as steep as in *Thalassocetus antwerpiensis*.[2] The supraorbital process bears a general resemblance to that of *Physeter catodon* and like the latter is largely uncovered by the maxilla externally. The postorbital projection extends farther backward than in the skull of a very young *Physeter*, although it does not come in contact with the zygomatic process. Below the apophysis of the maxilla, the short curved styliform process of the jugal is ankylosed to the lachrymal and forms the lower border of the orbit. On the skull of an adult *Physeter* the inferior arch is complete, but in a very young skull it is not complete, although the styliform process is slightly longer and narrower than on the Temblor skull. The lachrymal is wedged in between the preorbital margin of the supraorbital process of the frontal and the apophysis of the maxilla, and is largely concealed from a lateral view. The posterior face of the supraorbital process is truncated abruptly and the slope of the dorsal surface is relatively steep.

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[1] R. Kellogg, A fossil physeteroid cetacean from Santa Barbara County, California, Proc. U. S. Nat. Mus., vol. 66, Pub. 2564, 1–8, pls. 1–2, Feb. 28, 1925.

[2] O. Abel, Les Odontocètes du Bolderien (Miocène supérieur) d'Anvers., Mém. Mus. Roy. d'Hist. Nat. de Belgique, Bruxelles, tome 3, 73, text-fig. 8, 1905.

A short temporal fossa adds another distinctive feature to this skull. This fossa has been shortened in a fore-and-aft direction and is bounded by the frontal above and by the squamosal and alisphenoid below. The narrow parietal extending from the alisphenoid to the dorsal margin of the temporal fossa is one of the chief points of interest in this skull. The parietal apparently was not interposed between the transverse crest of the supraoccipital and the frontal as in *Thalassocetus*. The sutures are not as clearly shown in this region as might be desired, although the surface was etched with dilute hydrochloric acid to facilitate study. The suture between the frontal and parietal becomes very indistinct near the apex of the latter, although the posterior margin is rather clearly defined. Nevertheless, the suture between the maxilla and frontal is very deep above the apex of the parietal and since this suture extends backward beyond the level of the posterior margin of the parietal, there is ample evidence to indicate that the latter was shut off from the vertex and limited to the temporal fossa. The parietal of *Idiophyseter merriami* is relatively wider than in the Temblor skull. The condition of the parietal in the skull of the living sperm-whale, *Physeter catodon*, has been discussed by Flower and by the writer. These observations indicate that some of the stages through which the parietal has passed in the course of its reduction appear to be illustrated by *Thalassocetus*, *Idiophyseter* and *Aulophyseter*, culminating in *Physeter*, though the writer does not mean to convey the impression that these genera are derivatives of each other in the order in which they are given above. The reduction of the parietal, however, could and probably did pass through the stages illustrated by these genera, although they may not be closely related to one another.

The alisphenoid of the Temblor skull is much shallower than that of *Idiophyseter merriami* and it occupies essentially the same position in the temporal fossa. It extends forward to the supraorbital process of the frontal and contributes the posterior border of the optic channel. The alisphenoid is bounded superiorly by the frontal and parietal, and posteriorly by the squamosal.

The right zygomatic process is practically complete, although the outer surface is eroded in places. In general outlines, it bears a very close resemblance to that on a very young *Physeter* skull. From a lateral view the zygomatic process appears to be bluntly pointed anteriorly, but from a ventral view this extremity is seen to be rather slender. It is thickened dorso-ventrally and the upper surface slopes downward and forward; the post-glenoid process is not as well developed as on a very young *Physeter* skull and in the latter it is far from being conspicuous. The postorbital projection of the supraorbital process overhangs the extremity of the zygomatic process as in an adult *Physeter* skull.

The skull as a whole appears to be very solidly built and the slope of the dorsal and ventral contours impart a more or less triangular outline to the lateral view. The postpalatal axis bends downward from the horizontal axis of the rostrum. The hamular process is large and the deep plate of the pterygoid, with a convex inferior margin which projects inferiorly beyond the level of the lower border of the zygomatic process, illustrates the relative depth of this element. The opening between the hamular process and the deep plate of the pterygoid is shown in front of the extremity of the zygoma. The lateral extremity of the exoccipital is worn to some extent but not enough to cause one to misinterpret the original appearance of this bone. This portion of the exoccipital is rounded off in all directions and anteriorly the outer surface merges into that of the zygomatic process without any appreciable break in the general contour of this portion of the skull.

### VENTRAL VIEW

Before taking up in detail the relations of the various elements which form the ventral face of the skull attention may be directed to the remarkable preservation of the deep plates of the pterygoids and their hamular processes (pl. 2). The general contour of the skull is more or less pentagonal. As viewed from the ventral side, this skull exhibits a superficial resemblance to *Diaphorocetus poucheti*[1] and, as in the latter species, the greatest width of the skull is across the supraorbital processes. One important difference between the Temblor (pl. 3) and the Patagonian skull is shown by the implantation of the teeth. Alveoli for at least 13 or 14 teeth are present in each maxilla of the *Diaphorocetus* skull. The Temblor skull represents a more advanced stage in the evolutionary series of the physeteroids and one manifestation of this specialization appears to be found in the development of a shallow alveolar groove. The oldest known Miocene physeteroids as well as some of the later ones have well-defined alveoli in the maxilla for lodging the teeth. Functional teeth are not present in the upper jaw of the living sperm-whale, *Physeter catodon*, but as many as 8 atrophied teeth are sometimes implanted in the gum. There is a well-defined alveolar sulcus in the maxilla of the living pigmy sperm-whale, *Kogia breviceps*. If teeth were present in the upper jaw of the Temblor physeteroid, then it is reasonable to assume that they were also implanted in the gum as in *Physeter*. It is unlikely that alveoli may have been present in the extremity of the rostrum which is missing. The shallow closely approximated alveolar grooves of the Temblor skull, occurring as they do with other cranial features which undoubtedly represent a more specialized stage in the process which has been called telescoping, have suggested that the disappearance of the alveoli is one indication of an evolutionary advance, and that the thecodont dentition which characterized the Lower Miocene *Diaphorocetus* and *Idiorophus* and some of the Upper Miocene types, such as *Orycterocetus*, is the more primitive condition.

The ventral surface of the rostrum (pl. 3) is formed largely as by the maxillae, which approximate each other very closely mesially. The internal margins of the maxillae are in contact as far forward as the extremities of the palatines and then separate to allow the keel of the vomer to appear between them. For a distance of 465 mm., a narrow strip of the vomer is visible, but anteriorly it is shut off from a ventral view by the maxillae. The distal constriction of the rostrum is co-extensive with the shallow alveolar grooves. The wall which bounds the external margin of the left alveolar groove rises abruptly, but the internal margin is not so clearly defined and the surface slopes from the outer wall to the narrow mesial ridge which separates the two grooves. The posterior end of this alveolar groove is continuous with the dentinal canal which passes through the substance of the maxilla and emerges ventrally in the anterior infraorbital orifice. On the right side, there is a large circular cavity at the posterior end of the alveolar groove which may represent an abscess or tumor bearing some relation to the dentition. The remainder of the groove on the right side appears to have been obliterated to some extent by erosion. In *Idiophyseter merriami* the teeth were implanted near the outer margin of the maxilla in distinct alveoli. Beginning at the level of the posterior end of the alveolar groove, the oblique upward slope of the maxilla becomes more pronounced and is nearly vertical near the broken extremity of the right maxilla. Behind the posterior end of the alveolar groove the upward slope of the ventral face of the maxilla does not exceed 30°. There are two orifices for the infraorbital system on the ventral face of the maxilla. The anterior passage is entirely inclosed by the maxilla; the orifice looks outward and forward. The posterior orifice is bounded by the maxilla, frontal and lachrymal. These orifices are continuous with a large cavity in the maxilla which opens on the dorsal face of the skull in the maxillary incisure. A strip of the maxilla is likewise present between the same orifices on the

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[1] F. P. Moreno, Noticias sobre algunos Cetáceos fósiles y actuales de la República Argentina conservados en el Museo de La Plata, Revista del Museo de La Plata, tomo 3, pl. 10, 1892.

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skull of *Idiophyseter merriami*, but in the skull of a very young *Physeter catodon* it has disappeared and a single large orifice occupies approximately the same position as the two orifices on these fossil skulls.

On the right side of the skull, the lachrymal and jugal are essentially complete. The lachrymal is narrow and firmly lodged between the maxilla and the supraorbital process of the frontal. It contributes the lower margin of the antorbital notch and extends inward as far as the outer wall of the posterior infraorbital orifice. In its proportions and relations with the maxilla and frontal, the lachrymal of the Temblor skull bears some resemblance to that of *Diaphorocetus poucheti* and differs from *Idiophyseter merriami* chiefly in shape. There is no trace of a suture between the lachrymal and the curved process which forms the lower border of the orbit. It is probable that the entire bone must comprise the lachrymal and jugal, and that the free projecting portion of the bone represents the styliform process of the jugal as in living dolphins. This process is broad, sloping obliquely inward from the external to internal margins, with the outer border rounded and relatively thick, and the inner border very thin. It does not project halfway across the arch of the supraorbital process.

As mentioned in another part of this paper, the bones of the palatal region are remarkably well preserved. The external border of the left palatine is not complete. Fortunately, the one on the right side supplies any details which may be missing on the opposite palatine. Each palatine is mortised into the ventral face of the maxilla. The palatines of the Temblor skull are of medium size and do not project forward beyond the anterior margins of the anterior infraorbital orifices. They are overlapped posteriorly by the pterygoids. A narrow strip of the posterior extremity of the palatine appears in the lateral wall of the corresponding respiratory passage. The anterior borders of both palatines are emarginate and the external margin is more or less curved; the suture between the palatine and the pterygoid is convexo-concave. On comparing with the skull of very young *Physeter catodon*, the relations of the palatines to the surrounding bones were found to be essentially the same, except that the anterior extremities of the palatines of *Physeter* extend forward beyond the anterior infraorbital orifices. The well-defined mesial palatal and maxillary ridge of *Idiophyseter merriami* is not developed on the Temblor skull.

The hamular processes of the pterygoids are larger than those of a young *Physeter* skull and completely hide the respiratory passages from a ventral view. They project backward beyond the level of the optic canal. The lateral margins of the hamular processes are produced and overhang the steep plates of the pterygoids. For more than half of their length the internal margins of the hamular processes are in contact, but below the respiratory passages they commence to diverge, producing an outwardly curved margin.

A narrow strip of the vomer appears between the maxillae, but the remainder is not visible from a ventral view. With the exception of a short horizontally expanded strip which overrides the basisphenoid, the vomer takes the shape of a trough in the posterior end of which the presphenoid rests and, in front of the latter, separates the maxillae in the middle line of the rostrum. The vomer forms approximately the lower half of the internal and posterior wall for each respiratory passage, meeting the corresponding ectethmoid above. On the very young *Physeter* skull, thin wings of the vomer project laterally and are applied to the ventral face of the maxilla; the extremities of these lateral wings are visible in front of the optic canal between the posterior margin of the palatine and the frontal. These lateral processes of the vomer do not appear to have been developed on the Temblor skull, although similar processes were present in the skull of *Idophyseter merriami*.

The medial region of the basicranium is bounded laterally by the deep plates of the pterygoids and the adjoining falcate processes of the basioccipital. The area

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between these steep walls is more or less subtriangular in outline and relatively short. Into this region, the respiratory passages open. The falcate processes of the basioccipital project beyond the level of the condyles. Each falcate process is greatly thickened near the extremity. The body of the basioccipital is a relatively small bone terminated posteriorly by the paired condyles and fused anteriorly with the basisphenoid. Between the bases of the falcate processes and the deep plates of the pterygoids and near the level of the posterior margins of the latter, the surface of the combined basioccipital and basisphenoid is characterized by a mesial transverse swelling as in *Idiophyseter merriami*. The falcate processes of the basioccipital descend obliquely and are directed outward and backward. Each falcate process is in contact anteriorly with the deep plate of the pterygoid. Between the falcate process of the basioccipital and the small nodular paroccipital process is a deep jugular incisure.

In the skulls of the two living sperm-whales, *Physeter* and *Kogia*, and in the Miocene *Diaphorocetus* and *Idiophyseter*, we find, as might be expected, the same general plan of basicranial construction resulting from the horizontal expansion of the alisphenoid and the consequent flattening of the ventral surfaces of the alisphenoid and squamosal. The alisphenoid of the Temblor skull is likewise of large size and expanded horizontally. This bone is a relatively thin plate, bounded anteriorly by the supraorbital process of the frontal, suturally united posteriorly with the squamosal and in contact with the anterior surface of the exoccipital. When contrasted with *Diaphorocetus poucheti* and *Idiophyseter merriami*, the surface formed by the ventral faces of the alisphenoid and squamosal of the Temblor skull (pl. 4, fig. 2) is seen to agree in curvature and proportions. The horizontal expansion of the alisphenoid and the absence of a projecting glenoid process of the squamosal have resulted in the complete disappearance of the tympano-periotic recess in skulls of all known physeteroids. This recess is present in the skulls of all other described species of toothed whales and likewise occurs in the whalebone whales. The absence of an external reduplication of the pterygoid and the closure of the area usually occupied by the tympano-periotic recess by the broad horizontally expanded alisphenoid characterize the basicranium of all known physteroid whales. One result of this modification has been the closure and complete disappearance of some of the posterior basicranial foramina. The optic canal is confluent with the sphenoidal fissure as in *Idiophyseter*. This orifice is bounded by the vaginal plate of the pterygoid inferiorly, by the alisphenoid posteriorly, and by the supraorbital process of the frontal anteriorly and superiorly. The foramen ovale passes through the basal portion of the alisphenoid and its ectal orifice appears near the base of the superimposed deep plate of the pterygoid. With reference to the anterior margin of the squamosal, this orifice is placed relatively farther back than in *Idiophyseter* and does not open into a well-defined groove as in the latter. The ectal orifice of the carotid canal was not found.

Assuming that the skull of *Idiophyseter* belonged to a mature individual, there is no reason to suppose that the course of the jugulo-acoustic funnel is abnormal in any way. The course of this funnel is strongly oblique and it passes through the exoccipital.[1] In its present condition, the length of the funnel is about 90 mm. Turning to the Temblor skull, we find that the course of the jugulo-acoustic funnel is very oblique, forming an angle of 120° with the basicranial axis. It passes forward and upward through the exoccipital along the inner margin of the alisphenoid. The total length of the left jugulo-acoustic funnel is 207 mm. On the left side, about 115 mm. of the jugulo-acoustic funnel is exposed; the external border of the base of the deep plate of the left pterygoid, the internal border of the alisphenoid and a corresponding portion of the exoccipital have been eroded away, exposing a portion of the funnel. There is a second smaller canal, measuring 9 mm. in diameter at a point 120 mm. above the jugular incisure, internal to and parallel with the jugulo-acoustic canal. At the same level the jugulo-acoustic canal measures 18 mm. in diameter. The ectal end of the jugulo-acoustic funnel may have been characterized by a median constriction as in *Idiophyseter merriami*. This jugulo-acoustic funnel opens into the cranial cavity at a point about 65 mm. in front of the articular surface of the left condyle. The cranial cavity is relatively small for the size of the skull, but nevertheless this feature alone would not explain the unusual length of the jugulo-acoustic funnel. The median area formed by the basioccipital and the basisphenoid is short; the falcate processes of the basioccipital as remarked above are directed outward and backward, and project beyond the wing-like exoccipitals. In correlation with these modifications, the jugular incisure is correspondingly removed from the cranial cavity.

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[1] R. Kellogg, Additions to the Tertiary History of the Pelagic Mammals on the Pacific Coast of North America, Carnegie Inst. Wash., Pub. No. 348, 26, text-fig. 4, Apr. 22, 1925.

The body of the squamosal contributes a relatively small portion of the external wall of the braincase. It extends upward to the dorsal margin of the temporal fossa as a narrow wedge between the supraoccipital and the parietal, meeting the alisphenoid anteriorly and abutting against the exoccipital postero-inferiorly. A long curved suture marks the union of the squamosal with the alisphenoid on the basicranium. As viewed from below, the zygomatic process is rather slender. The glenoid fossa is shallowly concave and is not set off from the rest of the squamosal by an elevated internal margin; the postglenoid process is reduced to a narrow crest. Behind the postglenoid process a thin plate of the squamosal is applied to the exoccipital. In its outward course the external auditory meatus followed the crease behind the postglenoid process, but the usual groove is not defined very sharply.

## TEETH

Most of the teeth hereinafter described probably belonged in the lower jaws. Four teeth (pl. 7. figs. 1–4) were found embedded in the matrix surrounding the skull of the adult physeteroid. The crowns of two of these teeth (pl. 7, figs. 3, 4) curve forward and are compressed from side to side. The enamel on the crown is smooth in front and on one side; on the other side the enamel is slightly wrinkled, with poorly defined creases extending from the apex to the base of the crown. The enamel averages less than a millimeter in thickness. The crowns of both of these teeth are worn on their posterior surfaces. The enamel does not form an enlargement at the base of the crown and passes into the cement without any perceptible increase or decrease in the diameter of the neck. There is no distinct neck on either of these teeth. The greatest height of the enamel crown is about equivalent to one-third of the total length of the entire tooth. The roots of these teeth are long, curving backward, and are broadly oval in cross-section. The upper portions of the roots are somewhat swollen. On both of these teeth the distal end of the root is missing; the pulp cavity is closed. The crown has been destroyed on the largest (pl. 7, fig. 2) of these four teeth, but the extremity of the root is complete. The fourth tooth (pl. 7, fig. 1) is much slenderer than the others and the crown is worn on the posterior face in the same manner as on the two teeth described above.

Five additional teeth (pl. 7, figs. 5–9) from the same stratum and from the same trench were secured a month or so later by the California Academy of Sciences. Three of these teeth (pl. 7, figs. 5, 7, 8) agree in most particulars with those associated with the adult skull. The largest of these five teeth (pl. 7, fig. 6), measuring 123.4 mm. in its present condition, is characterized by a swollen root and by the complete closure of the pulp cavity; the extremity of the root is missing. The greatest antero-posterior diameter of the root is 37.3 mm. and the greatest transverse diameter is 31.8 mm. The maximum thickness of the outer layer of cement appears not to exceed 5.4 mm. and it thins out very abruptly above the most gibbous portion of the root. The cementum does not approach within 5 mm. of the base of the enamel crown, exposing a band of dentine of varying width on the neck. The swelling of the root is most pronounced on one side and on the front; the other side is somewhat flattened, with a shallow longitudinal depression which becomes more pronounced as it approaches the extremity. At one point on this face, the cementum does not come within 26 mm. of the base of the enamel crown. In appearance, the enamel on the crown resembles that on the teeth described above; the apex of the crown is worn off.

In some respects the remaining tooth (pl. 7, fig. 9) is the most peculiar of all. Most of the crown has been worn off, but the root is complete. The root curves backward and tapers to the extremity which is compressed antero-posteriorly and covered with small nodosities; the anterior face of the root is evenly convex, but the root appears to be deformed when viewed from the rear. The root is constricted on one side above the middle, forming an elongate depression on the posterior face behind the constriction. The outer layer of cement completely covers the central core of dentine and extends upward to the base of the enamel crown.

The four teeth associated with the adult skull of the Temblor physeteroid do not exhibit any close resemblance to teeth found in Australia and Tasmania. The tooth of *Scaptodon lodderi*,[1] which was washed up at Ulverstone, N. W. Tasmania, after a heavy gale, must have had a quite different type of crown than that of the Temblor physeteroid because the cement extends nearly to the apex; the tooth as a whole is considerably larger and the root is narrowly elliptical in cross-section. The tooth of *Scaldicetus lodgei*[2] found at Clifton Bank, Muddy Creek, near Hamilton, Victoria, Australia, has a much more slender root; the enamel on the crown is finely striated and crenulate, and the crown is equal to one-sixth of the entire length of the tooth (102.5 mm.). The formations in which these teeth were found have been assigned to the late Oligocene and early Miocene.

In the Kalimnan series of Australia, which has been tentatively referred to the Lower Pliocene, two other species have been described from teeth. *Scaldicetus macgeei*[3] is known only from a single imperfect tooth obtained from the ferruginous and calcareous clays of the Beaumaris Cliffs in Victoria, Australia. In its present condition, this conical tooth measures 118 mm. in length and the pulp cavity at the base 43 mm. in

*Measurements of the teeth (in millimeters)*

| | Pl. 6, fig. 1 | Pl. 6, fig. 2 | Pl. 6, fig. 3 | Pl. 6, fig. 4 | Pl. 6, fig. 5 | Pl. 6, fig. 6 | Pl. 6, fig. 7 | Pl. 6, fig. 8 | Pl. 6, fig. 9 |
|---|---|---|---|---|---|---|---|---|---|
| Greatest height of the crown.............. | 23+ | ...... | 29.5+ | 31+ | ...... | 19.6+ | 29.8 | 31.6 | ...... |
| Greatest antero-posterior diameter of crown at base........ | 14.2 | 21 | 22.5 | 22.2 | ...... | 18.9 | 18.8 | 20.9 | 13.4 |
| Greatest extero-internal diameter of crown at base................ | 12.5 | 18 | 16 | 16.6 | ...... | 16.5 | 15.5 | 13.5 | 13.8 |
| Greatest length of tooth as preserved (in a straight line)........ | 92.5 | 101 | 93 | 92 | 96.8 | 123.4 | 108.7 | 103 | 96.5 |
| Antero-posterior diameter of most expanded portion of root....... | 18.5 | 26.2 | 26.5+ | 27+ | 19.8 | 37.3 | 25.3 | 24.5 | 30.2 |

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[1] F. Chapman, On an Apparently New Type of Cetacean Tooth from the Tertiary of Tasmania, Proc. Roy. Soc. Victoria (n. s.), vol. 30, pt. 2, 150–152, pl. 27, Mar. 1918.

[2] F. Chapman, New or Little-known Victorian Fossils in the National Museum, Proc. Roy. Soc. Victoria, (n. s.), vol. 30, pt. 1, 34–35, pl. 4, fig. 6, July 1917.

[3] F. Chapman, On the Occurrence of Scaldicetus in Victoria, Records Geol. Surv. Victoria, vol. 3, pt. 2, 236–238, pl. 40, 1912.

diameter. The enamel crown, approximately 42 mm. in height, is "rugosely vertically striated." The other species, *Physetodon baileyi*[1] was also based on a single tooth obtained at Mordialloc [ = Beaumaris] near Melbourne, Australia. This tooth measures about 10 inches in length and is 2 inches wide near the middle of the root.

### Periotic

The right periotic (pl. 8, fig. 1, and pl. 9, fig. 3) here discussed was not attached to the skull and were it not for the fact that this is the only type of physeteroid periotic represented among the many specimens obtained from a short trench dug in the uppermost horizon of the Temblor formation, there might be some question as to its allocation. Eight right and three left periotics of this physeteroid were obtained at this locality.

It is remarkable how closely, except for minor modifications in the anterior process, this periotic resembles those of the living sperm whales, for the relative proportions and peculiarities of the various structures are essentially the same. As in other spermwhales, the periotic may be divided for purposes of description into a very dense external portion, the combined anterior and posterior processes, a lighter internal sub-hemispherical *pars cochlearis* and the *pars vestibularis*. Minor variations in the contour of the articular facet on the posterior process (pl. 8, figs. 1–6) are observable in the eleven periotics under consideration, but most of these may be attributed to the effects of erosion. There are fine osseous crests on the tympanic face of the posterior process which are arranged like rays radiating from a common center on the internal margin. This articular facet is irregular in outline, with the posterior margin rather evenly curved and with the external and anterior margins more or less sinuous. The major portion of the posterior facet is concave, but the anterior border slopes obliquely to the groove above the external auditory tube. The ventro-internal border of this process projects inward and the free edge contributes the floor of the facial canal for approximately half of its length. The external face of this process is flattened and more or less rugose. According to the text-figure and photographs reproduced in the memoir by Abel[2] for the right and left periotics which are unfortunately allocated to *Eurhinodelphis longirostris*, it is evident that the distal or external portion of the posterior process is distinctly emarginate and rugose.

There is very little variation in the general outlines of the *pars cochlearis* as seen from a ventral view in these eight periotics. Whatever differences are observable are of a minor nature. There is a low short crest or nodosity near the middle and on the internal border of the *pars cochlearis* on nine of these periotics, which may have resulted from contact with the involucrum of the tympanic. The major portion of the ventral face of the *pars cochlearis* is more or less flattened and slopes toward the anterior margin, with the most inflated point opposite to the fenestra ovalis. The external face is flattened and nearly vertical. From a tympanic view three apertures are visible and of these the largest is the fenestra rotunda on the posterior face of the labyrinthic region. This fenestra is crescentic in outline with a rounded nodosity above, which partially closes the opening. The fenestra ovalis is ovoidal in outline and is situated near the center of the tympanic face of the periotic. A narrow rim which is raised above the canal for the facial nerve and the fossa for the stapedial muscle encircles the fenestra on the outside. The foot plate of the stapes completely fills the fenestra. A medium-sized internal passage which leads from the vestibule and a pair of minute antero-external foramina which lead to the semi-circular canals also open into the vestibule. The minute aqueduct leading from the foramen singulare opens near the bottom of the vestibule on the internal wall and near the anterior angle. The epi-tympanic orifice of the *aquaeductus Fallopii* and the fenestra ovalis lie in a depression, although the former is largely concealed from a ventral view by the projecting ledge of the *fossa incudis*. Posterior to this orifice, the facial canal is open along its whole length, sloping obliquely downward and curving around the posterior face of the posterior process. Posteriorly, the facial canal borders on a large semi-enclosed fossa for the stapedial muscle. The fossa for the stapedial muscle is a deep concavity and the surface for the attachment of the muscle extends downward upon the external face of the *pars cochlearis*. A thin-edged crest is developed on the ventro-external angle of the cochlear region by the encroachment of the fossa for the stapedial muscle. This thin curved crest which rises behind the stapedial fossa has been destroyed on eight of these periotics, including that associated with the type skull, but is well preserved on three. Between the fenestra ovalis and the deep concave fossa for the head of the malleus, there is a narrow crescentic excavation which commences near the epi-tympanic orifice of the *aquaeductus Fallopii* and extends downward on the external face of the *pars cochlearis* to its tympanic face. Between the rounded tuberosity or swelling on the anterior process and the anterior margin of the articular facet on the posterior process, the ventral surface of the external denser portion of the periotic is hollowed out, becoming distinctly grooved as it approaches the *fossa incudis*. On seven of these periotics the *fossa incudis* is preserved in its entirety, but it has been damaged on the periotic associated with the type skull. This small shallow elliptical fossa is situated at the extremity of the thin ledge which projects inward below the facial canal. The *fossa incudis* receives the *crus breve* of the incus.

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[1] F. McCoy, Prodromus of the Palaeontology of Victoria, Decade 6, Geol. Survey Victoria, Melbourne, 19–20, pl. 55, figs. 1–2, 1879.

[2] O. Abel, Les dauphins longirostres du Boldérien (Miocène supérieur) des environs d'Anvers, Mém. Mus. Roy. d'Hist. Nat. de Belgique, Bruxelles, tome 2, 121–123, text-fig. 19, and pl. 17, figs. 11, 12, 1902.

The extremity of the anterior process resembles the handle end of a crutch when viewed from in front. This peculiarity is produced by two projecting points, the external and internal angles. There is a crease, more distinct on some than on others, on the posterior face of the tuberosity external to the epi-tympanic orifice of the *aquaeductus Fallopii*. The external face of the anterior process is rounded off between this tuberosity and the apex of the process. Anterior to the fossa for the head of the malleus, the ventral surface of the anterior process is deeply concave from end to end and more or less flattened from side to side. The relatively large accessory ossicle or unciform process of the tympanic is lodged in this fossa. Accessory ossicles were present on all eleven of these periotics. The accessory ossicle is relatively large, almost egg-shaped, with a longitudinal groove marking the line of ankylosis with the external lip of the tympanic and fusing with the anterior process of the periotic along its posterior and external margins. If this ossicle is forcibly removed, small portions of the corresponding surface of the anterior process break away with it. When the accessory ossicle is in position, it contributes the outer wall of the deep notch between it and the *pars cochlearis*.

Most of the depressions and nodosities observed on the denser external portion of the cerebral face of the periotic do not appear to have any deep-seated significance. Four of these periotics have a rather prominent pyramidal tuberosity arising external to the orifice of the *aquaeductus vestibuli* and three do not exhibit any trace of this nodosity. On two there is a large nodosity external to the entrance to the *aquaeductus Fallopii*. On all of these periotics a broad groove, irregular in appearance because of the presence of small nodosities, traverses the anterior process in front of the *pars cochlearis*. From a cerebral view the posterior process appears rather slender and the anterior process very robust; the *pars cochlearis* is inclined forward. An irregular crease defines the limits of the *pars vestibularis* and the posterior process on the cerebral face of the periotic. The *pars vestibularis* is relatively small; its external surface is concealed by the anterior and posterior processes, and internally it is continuous with the *pars cochlearis*.

A rather instructive example of how slight changes in the growth of a bony partition between the entrance to the *aquaeductus Fallopii* and the more centrally placed *tractus spiralis foraminosus* can modify the contour of the internal acoustic meatus is shown in these eleven periotics (pl. 9, figs. 1–6). The internal acoustic meatus of the type periotic represents the average type. In the majority of these periotics the rim of the internal acoustic meatus is pyriform in outline. In others a thin partition or transverse crest is interposed between the entrance to the *aquaeductus Fallopii* and the fossa bounding the spiral tract, whose outer edge is almost continuous with the rim of the meatus and imparts a distinctly ovoidal outline to the latter. The largest and most external of the orifices which appear on the cerebral face is that of the *aquaeductus Fallopii*, which pierces the substance of the periotic and through which passes the facial nerve to emerge on the tympanic face slightly anterior to the *fenestra ovalis*. Internal to the entrance to the *aquaeductus Fallopii* is the deep internal acoustic meatus,

*Measurements of the periotic (in millimeters)*

| | No. 11230, U. S. N. M. Right periotic type | No. 10853, U. S. N. M. Right periotic | No. 2798, C. A. Sci. Right periotic | No. 2795, C. A. Sci. Right periotic | No. 2794, C. A. Sci. Right periotic | No. 2797, C. A. Sci. Right periotic | No. 2799, C. A. Sci. Left periotic | No. 2800, C. A. Sci. Right periotic | No. 2801, C. A. Sci. Right periotic |
|---|---|---|---|---|---|---|---|---|---|
| Breadth of periotic at level of Fenestra ovalis (as measured from external face above excavation to internal face of pars cochlearis).... | 25.2 | 26 | 25.1 | 28.5 | 25 | 27.8 | 26.1 | 27 | 23.1 |
| Greatest length of periotic (tip of anterior process to tip of posterior process)........... | 38.1 | 41+ | 37.6+ | 42 | 36.2 | x | x | 42.5+ | 36.7+ |
| Greatest dorsoventral depth of periotic (as measured from most inflated portion of tympanic face of pars cochlearis and external excavation to most projecting point on cerebral face)...... | 21 | 19.5 | 19 | 17 | 16.8 | 19.7 | 17.5 | 21.3 | 17.9 |
| Distance between Fenestra rotunda and tip of anterior process........... | 26.8 | 29.1 | 26.1 | 28.3 | 26 | 28.7 | 27.6 | 28 | 25 |
| Distance between Fenestra rotunda and tip of posterior process........... | 19+ | 22.9+ | 18.3 | 20.2 | 17.2 | x | x | 21.5 | 18 |
| Distance between epitympanic orifice of Aquaeductus Fallopii and tip of anterior process.... | 18.8 | 21.5 | 20 | 21.5 | 19.1 | 21.2 | 19.4 | 20.7 | 18.7 |

on the bottom of which is the *tractus spiralis foraminosus* and the minute *foramen centrale*. On the external wall of this meatus and about halfway between the rim and the bottom is a small compressed *foramen singulare*. A relatively thin partition or transverse crest, whose outer margin may or may not be depressed below the level of the rim of the internal acoustic meatus, places the orifice of the *aquaeductus vestibuli* outside of and posterior to the meatus. This orifice is compressed and opens into a slit-like fossa. The cerebral orifice of the *aquaeductus cochleae* is considerably larger than that for the *aquaeductus vestibuli*, and the interval between these orifices varies from 2 to 3.8 mm.

## SKULL OF YOUNG

A number of fragments of skulls belonging to young sperm-whales were encountered in the excavations made on Shark Tooth Hill. Most of these scattered fragments add very little to what is known concerning this cetacean. A considerable portion of the skull of a young individual, however, was found within 20 feet of the adult skull. As will be noted on the photographs reproduced on plates 5 and 6, a considerable portion of this skull is missing. Before preparation the skull showed clearly that it had suffered from the effects of crushing; the bones which comprise the rostrum are not complete and all of the basicranium is missing. It lay on its ventral face and most of the bones included in the braincase are not represented, although the exoccipitals and portions of the supraoccipital are preserved.

The most interesting peculiarity of this skull (pl. 6, fig. 2), one that distinguished it from the other known genera as pointed out in the discussion of the adult skull, is the presence of a shallow alveolar groove in each maxilla. These grooves are relatively wider apart than on the adult skull and there are no indications of septa. These alveolar grooves are no longer relatively than those on the adult skull.

Erosion as well as the decay of bony tissue preceding fossilization have exposed portions of the aqueduct which conveys the nerves and blood-vessesls that supply the teeth in the right maxilla. It seems unnecessary to describe some of the structural features of the skull of this young whale, especially as no additional peculiarities are observable. It will be noted that the premaxillae (pl. 6, fig. 1) are unusually broad as in the adult skull, but their internal borders, which project inward above the mesorostral gutter, as well as their posterior extremities have been destroyed. In their relations with the surrounding bones, the premaxillae also agree with the adult skull.

The contour of the rostrum differs but little from that of the adult skull. Owing to a more oblique orientation of the two halves of the rostrum, the antorbital notches, as viewed from above, appear to be narrower than on the adult skull. The photograph of the ventral surface reproduced on plate 6 shows that these antorbital notches are not unlike those on the adult skull (pl. 3). The lachrymal occupies the same relative position and there is no indication of a suture between it and the styliform jugal. There are two ventral orifices for the infraorbital system in each maxilla.

It is fortunate that the right maxilla of this young skull is so well preserved in the region of the maxillary incisure. The incisure is relatively large and looks forward and upward. Behind this incisure, there is a large cavity or passage within the maxilla which is part of the infraorbital system. It is roofed over by a thin plate of the maxilla. In addition to the maxillary incisure and the two orifices on the ventral face of the maxilla there is a rather large posterior maxillary foramen which opens dorsally and looks outward and backward. The thin plate which contributes the roof for the cavity in the maxilla has been destroyed on the left maxilla and the posterior ventral infraorbital orifice may be seen below.

No additional peculiarities are shown on the lateral view (pl. 5, fig. 2) of the young skull. The supraorbital process and the curvature of the suture between the maxilla and frontal above the orbit correspond with the adult skull.

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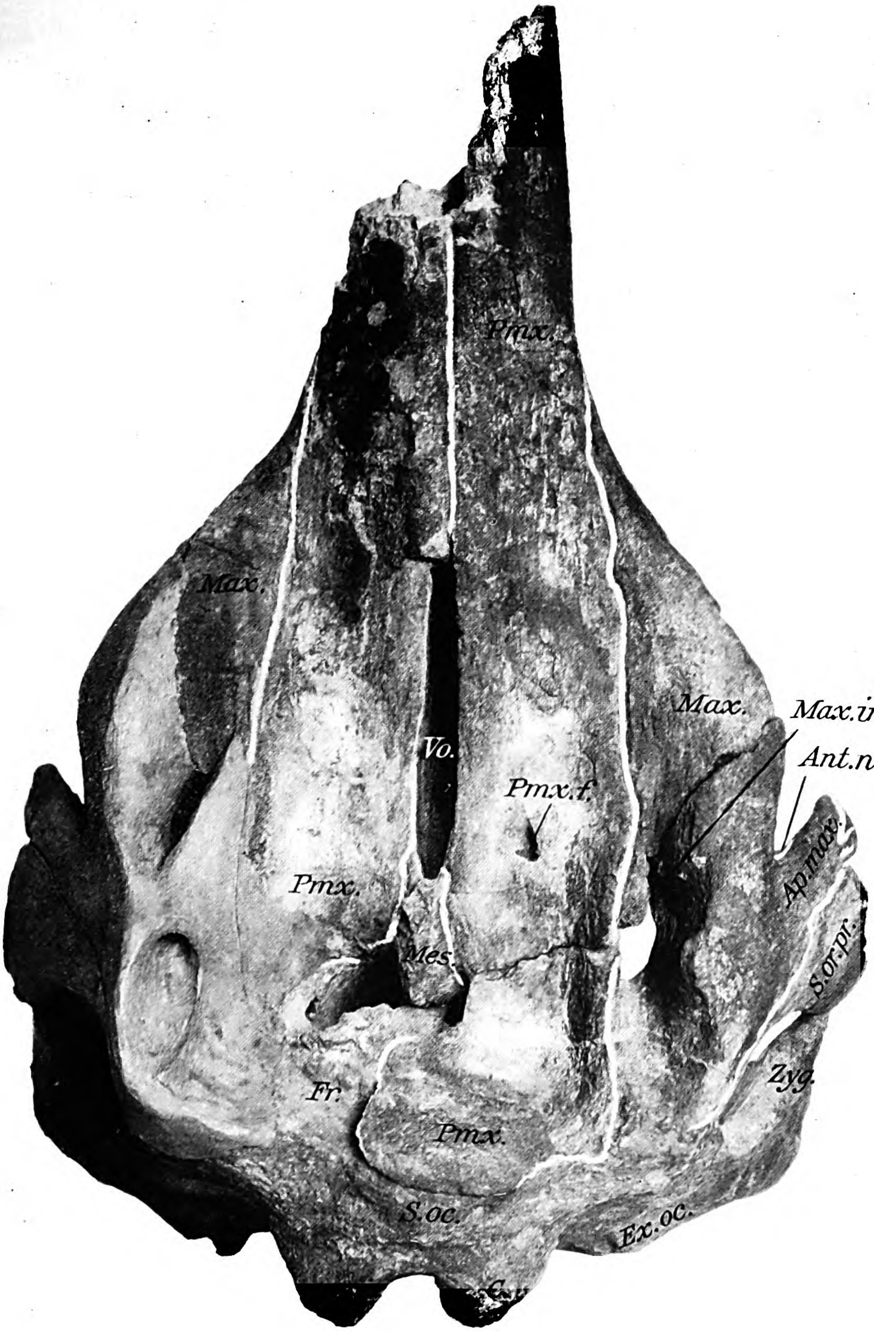
*Measurements of skull (in millimeters)*

| | Cat. No. 11230, U.S.N.M. Adult | Cat. No. 11313, U.S.N.M. Young |
|---|---|---|
| Total length as preserved (condyles to tips of premaxillae) | 1114 | x |
| Total length as estimated (condyles to tips of premaxillae) | 1210 | x |
| Length of rostrum as preserved (antorbital notches to extremity) | 712 | x |
| Total length of rostrum as estimated (antorbital notches to extremity) | 800 | x |
| Breadth of rostrum at antorbital notches as restored | 558 [1] | 354 |
| Breadth of rostrum at swelling in front of antorbital notches as restored | 595 [1] | 360 |
| Greatest breadth of skull across supraorbital processes, as restored | 725 [2] | 490 |
| | 748 [3] | x |
| Greatest breadth of skull across zygomatic processes of squamosals | 718 | x |
| Vertical height of skull (basioccipital to transverse crest) | 298+ | x |
| Vertical height of skull (hamular process of pterygoid to transverse crest) | 443+ | x |
| Vertical height of rostrum at base (at level of antorbital notches) | 177 | x |
| Greatest width of right maxilla from a ventral view (inside margin to apophysis) | 363 | 210 |
| Greatest length of right premaxilla as preserved | 988 | x |
| Greatest breadth of right premaxilla at level of nares | 121 | 82 |
| Greatest breadth of right premaxilla posterior to nares | 197 | x |
| Least breadth of right premaxilla in front of antorbital notches | 113 | 74+ [4] |
| Greatest antero-posterior diameter of supraorbital process of right frontal at extremity | 137 | 100 [5] |
| Greatest thickness of preorbital portion of supraorbital process of right frontal | 40 | x |
| Elevation of lateral crest of supracranial basin above orbit | 250 | x |
| Least breadth of supraoccipital between temporal fossae | 480 | x |
| Distance from summit of transverse crest to upper margin of foramen magnum | 133+ | x |
| Height of foramen magnum | 78 | x |
| Breadth of foramen magnum | 95 | x |
| Greatest distance between outside margins of occipital condyles | 248 | x |
| Greatest vertical diameter of left condyle | 158 | x |
| Greatest transverse diameter of left condyle | 96 | x |
| Distance across skull between outer margins of exoccipitals | 700 | x |
| Distance between anterior margin of apophysis of supraorbital process of right frontal and posterior margin of right condyle | 493 | x |
| Distance across basicranium between foramina ovale | 204 | x |
| Total length of vomer | 780 | x |
| Greatest length of left palatine | 238 | x |
| Greatest breadth of left palatine | 135 | x |
| Greatest length of left pterygoid | 293 | x |
| Greatest length of hamular process of right pterygoid | 185 | x |
| Greatest transverse diameter of right lachrymal | 198 | 151 [5] |
| Greatest antero-posterior diameter of right lachrymal | 75 | 68.5 [5] |
| Greatest length of right jugal | 107 | 62+ [5] |
| Greatest length of right zygomatic process | 198 | x |
| Greatest breadth of right alisphenoid at extremity | 110 | x |
| Greatest depth of right alisphenoid at extremity | 30 | x |
| Least distance between optic canal and foramen ovale | 86 | x |
| Least distance between optic canal and jugulo-acoustic canal | 162 | x |
| Greatest diameter of right respiratory passage | 48 | 24 |
| Greatest diameter of left respiratory passage | 85 | 49 |

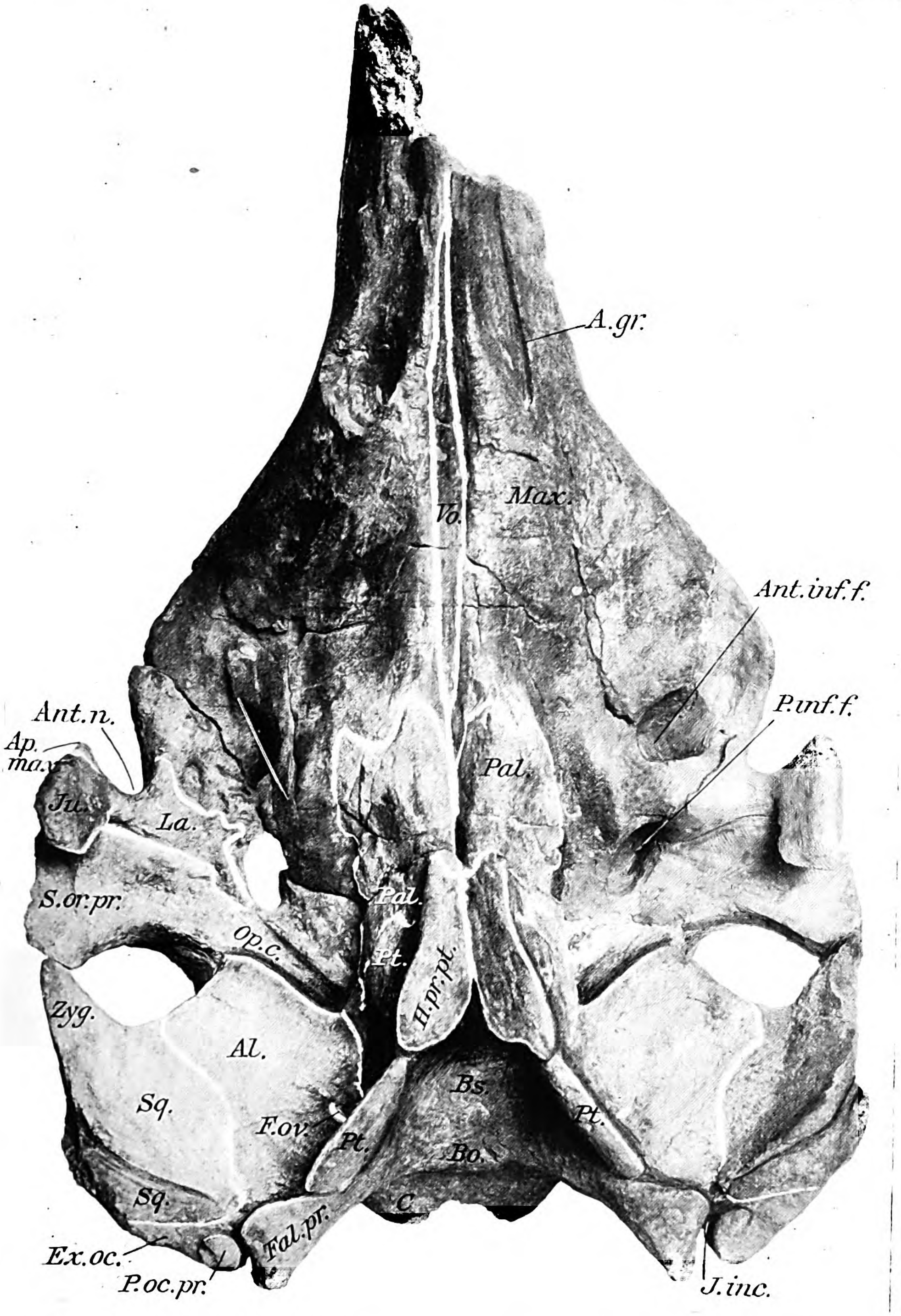
[1] Estimated; [2] Anteriorly; [3] Posteriorly; [4] Inner border missing; [5] Left.

## ABBREVIATIONS FOR PLATES 1 TO 6

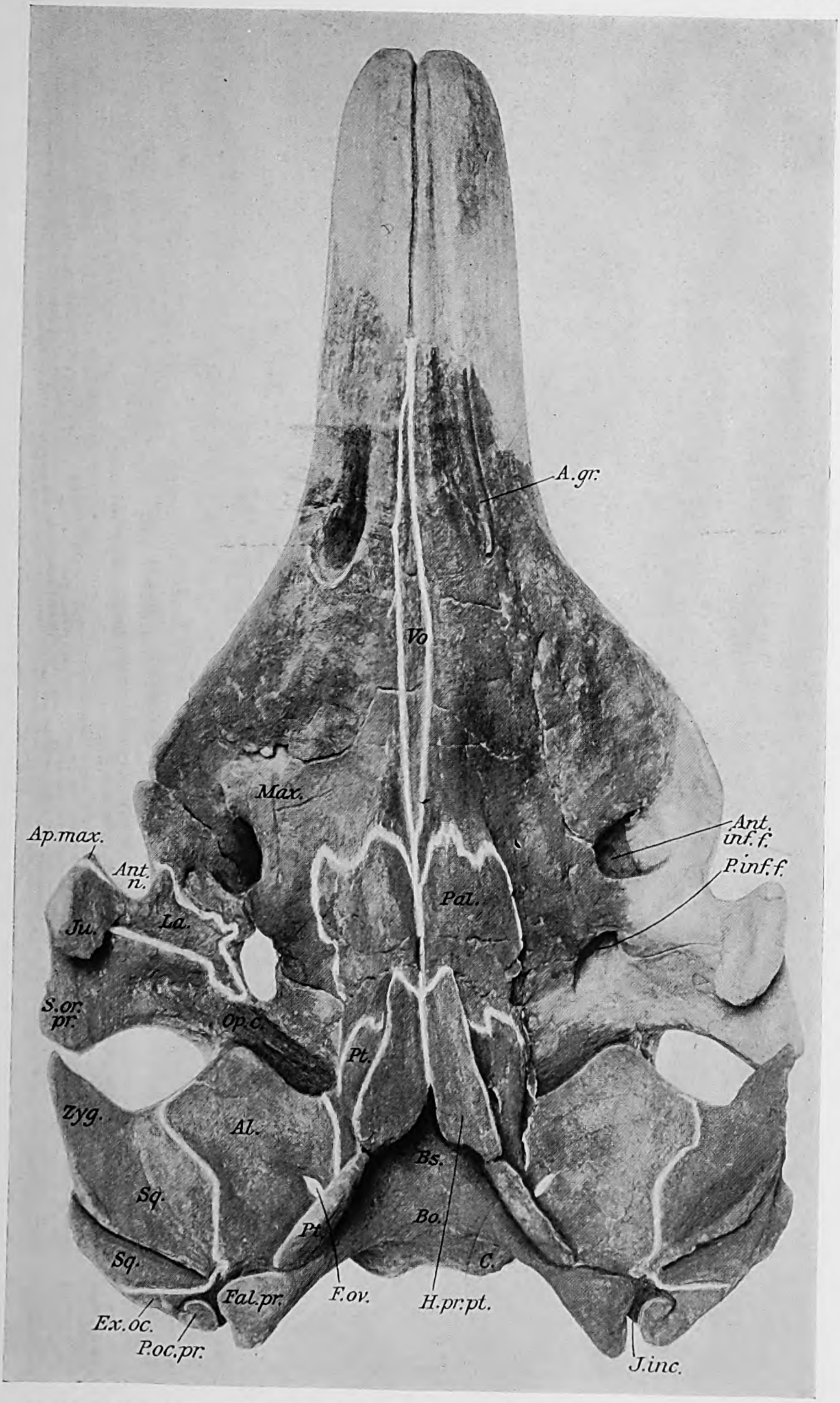
*A. gr.*, alveolar groove
*Al.*, alisphenoid
*Ant. inf. f.*, anterior infraorbital foramen
*Ant. n.*, antorbital notch
*Ap. max.*, apophysis of maxilla
*Bo.*, basioccipital
*Bs.*, basisphenoid
*C.*, condyle
*Ex. oc.*, exoccipital
*Fal. pr.*, falcate process of basioccipital
*F. hyp.*, hypoglossal foramen
*F. m.*, foramen magnum
*F. ov.*, foramen ovale
*Fr.*, frontal
*H. pr., pt.*, hamular process of pterygoid
*J. A. C.*, jugulo-acoustic canal
*J. inc.*, jugular incisure
*Ju.*, jugal
*La.*, lachrymal
*Max.*, maxilla
*Max. inc.*, maxillary incisure
*Mes.*, mesethmoid
*Op. c.*, optic canal
*Pa.*, parietal
*Pal.*, palatine
*P. inf. f.*, posterior infraorbital foramen
*P. max. f.*, posterior maxillary foramen
*Pmx.*, premaxilla
*Pmx. f.*, premaxillary foramen
*P. oc. pr.*, paroccipital process
*Pt.*, pterygoid
*R. N. A.*, right respiratory passage
*S. oc.*, supraoccipital
*S. or. pr.*, supraorbital process of frontal
*Sq.*, squamosal
*Vo.*, vomer
*Zyg.*, zygomatic process of squamosal



Dorsal view of type skull of *Aulophyseter morricei*. U. S. Nat. Mus., Cat. No. 11230. Restored areas on left side appear lighter than original surface.



Ventral view of type skull of *Aulophyseter morricei*. Supraorbital process of left frontal and overlying maxilla restored. U. S. Nat. Mus., Cat. No. 11230.



Ventral view of type skull of *Aulophyseter morricei*. Supraorbital process of left frontal, overlying maxilla and extremity of rostrum restored. U. S. Nat. Mus., Cat. No. 11230.

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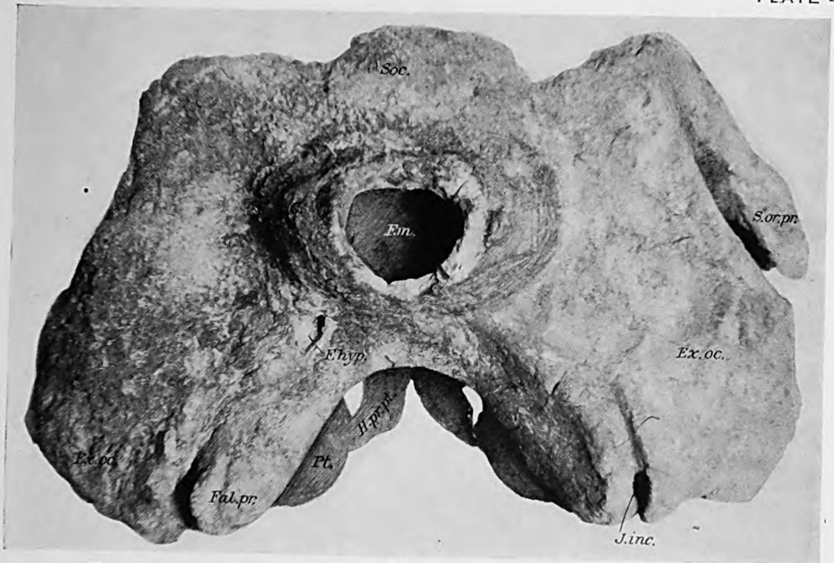

Fig. 1—Posterior view of type skull of *Aulophyseter morricei*. U. S. Nat. Mus., Cat. No. 11230.

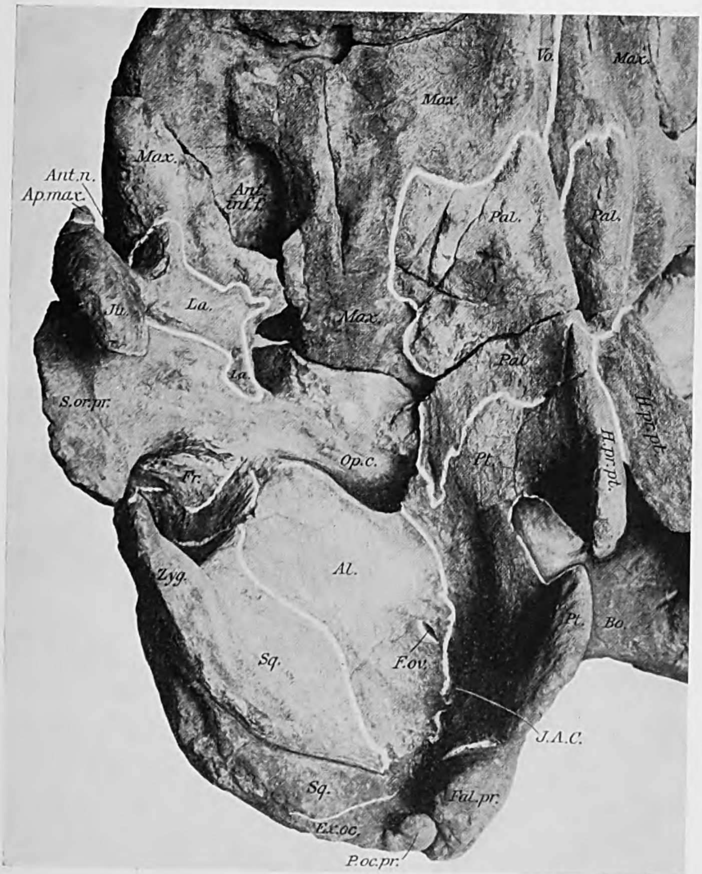

Fig. 2—Oblique view of ventral face of type skull of same, showing relations of pterygoids and palatines.

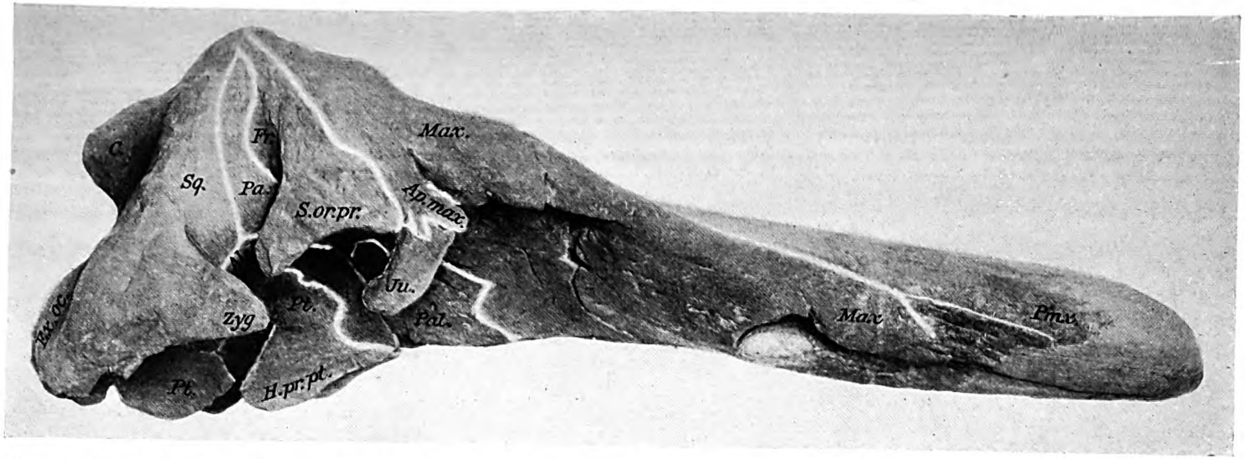

FIG. 1—Lateral view of type skull of *Aulophyseter morricei*. U. S. Nat. Mus., Cat. No. 11230. Extremity of rostrum restored.

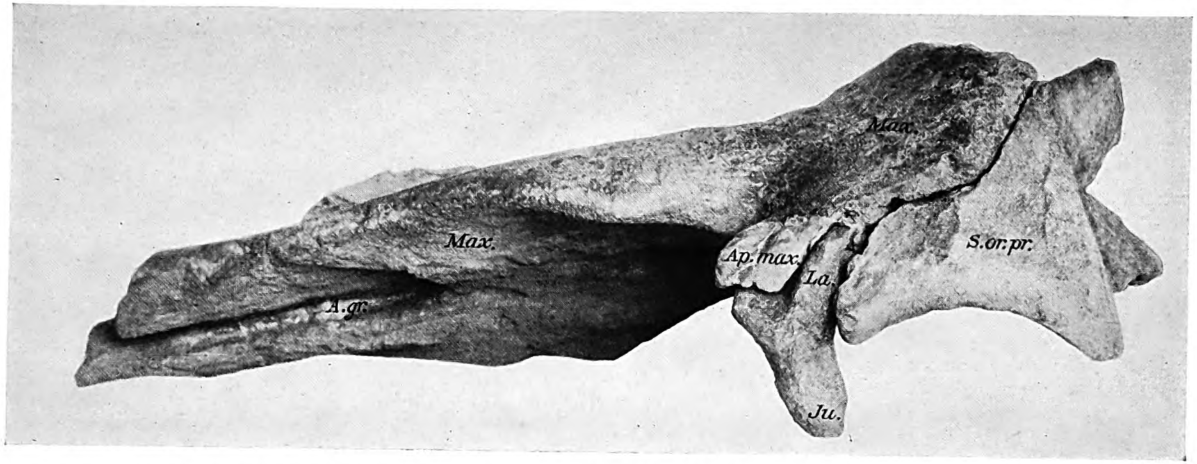

FIG. 2—Lateral view of skull of a young *Aulophyseter morricei*. U. S. Nat. Mus., Cat. No. 11313. The braincase and extremity of rostrum are missing.

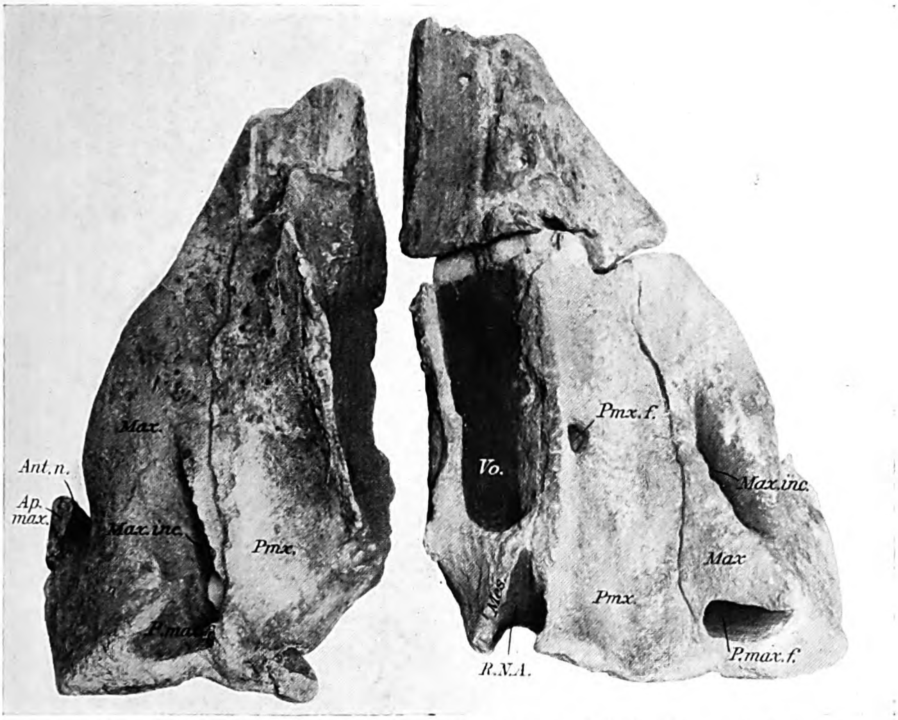

FIG. 1—Dorsal view of incomplete skull of a young *Aulophyseter morricei*.
U. S. Nat. Mus., Cat. No. 11313.

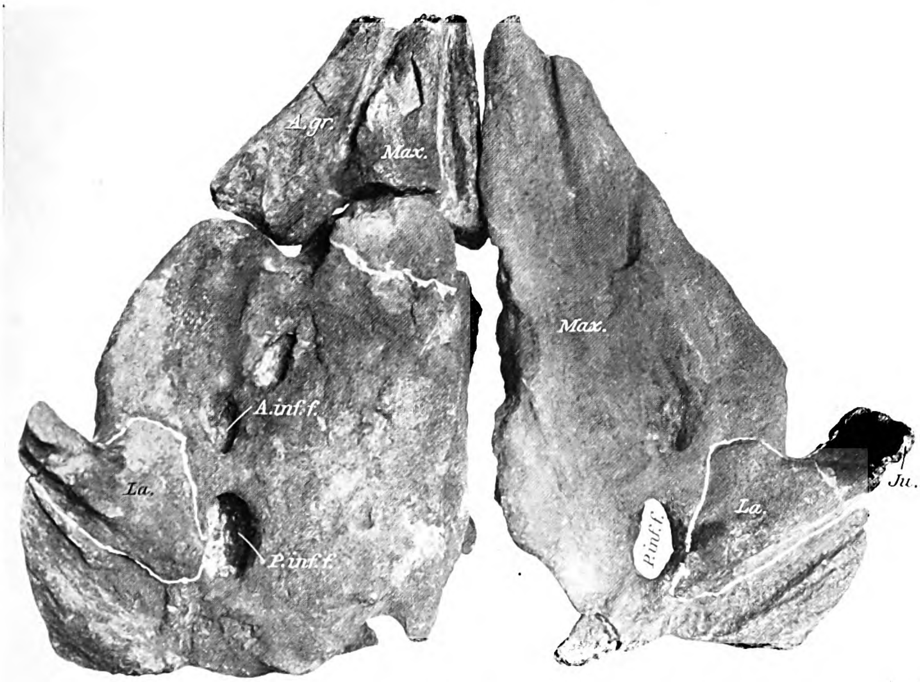

FIG. 2—Ventral view of incomplete skull of same.

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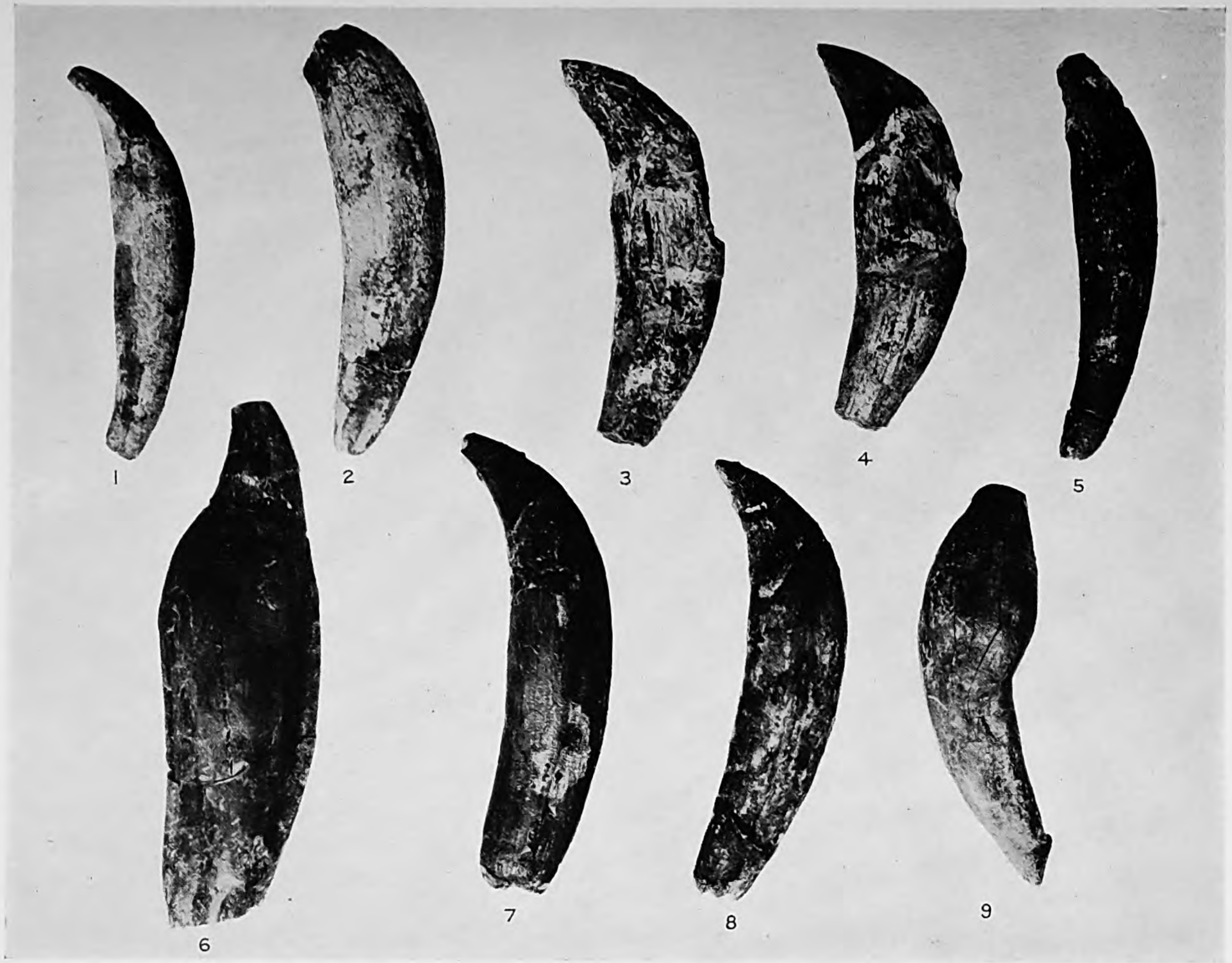
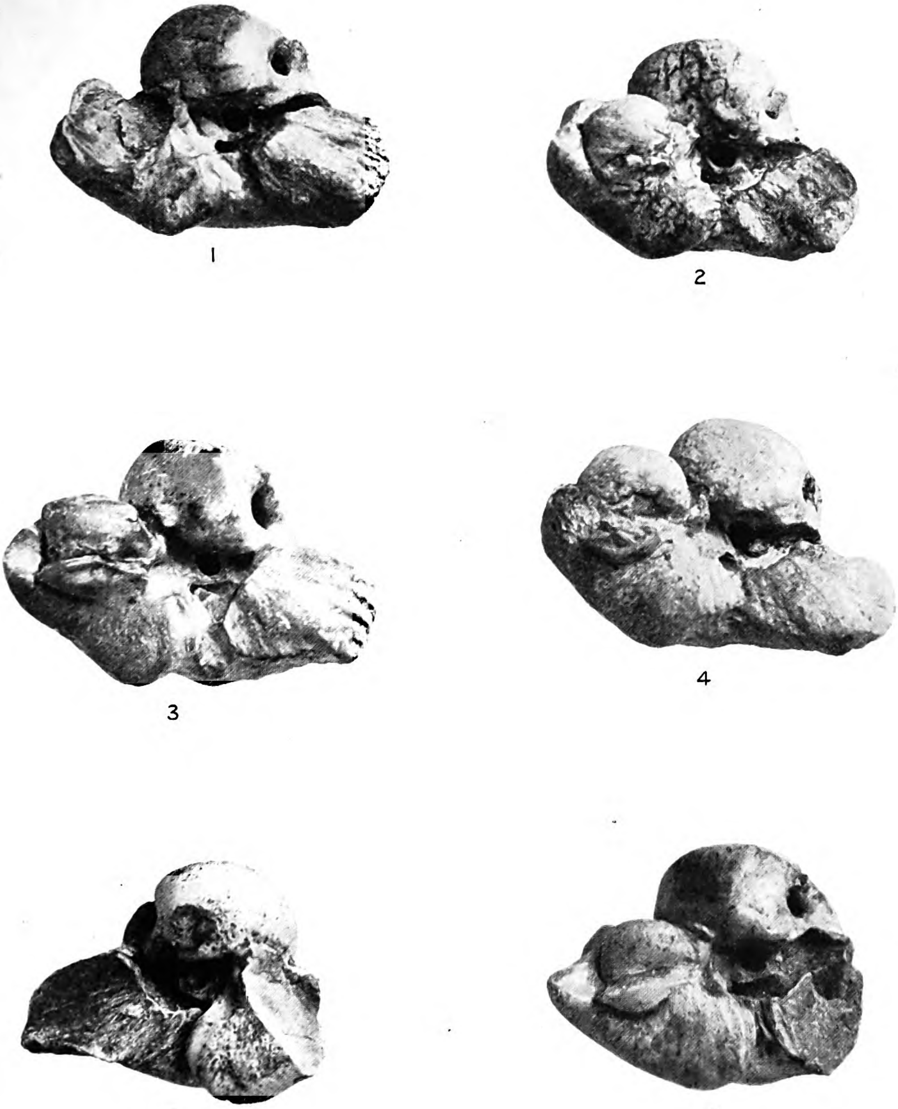
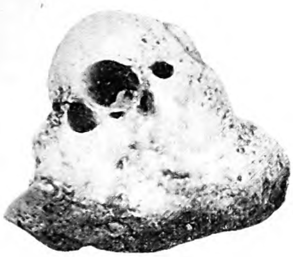


FIGS. 1–4—Teeth found embedded in matrix surrounding adult skull of *Aulophyseter morricei.* U. S. Nat. Mus., Cat. No. 11230.
FIGS. 5–9—Teeth found in same stratum as adult skull, but not associated with it. Cat. Nos. 2806, 2802, 2803, 2804, and 2805, Calif. Acad. Sci.



Figs. 1–6—Tympanic views of periotic bones of *Aulophyseter morricei.*
(1) Right periotic, with accessory ossicle removed. U. S. Nat. Mus., Cat. No. 11230.
(2) Right periotic, with accessory ossicle attached. Calif. Acad. Sci., Cat. No. 2794.
(3) Right periotic, with accessory ossicle attached. Calif. Acad. Sci., Cat. No. 2795.
(4) Right periotic, with accessory ossicle attached. U. S. Nat. Mus., Cat. No. 10853.
(5) Left periotic, anterior process missing, Calif. Acad. Sci., Cat. No. 2796.
(6) Right periotic, posterior process missing, Calif. Acad. Sci., Cat. No. 2797.



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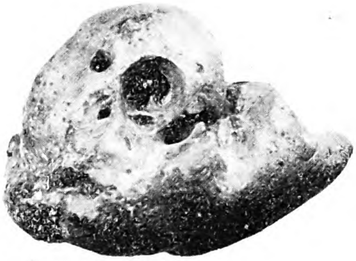

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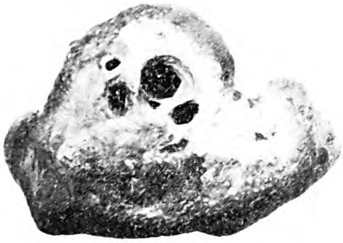

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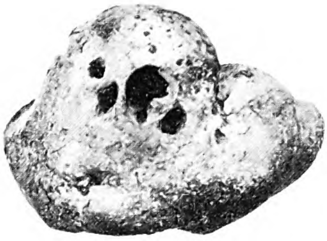

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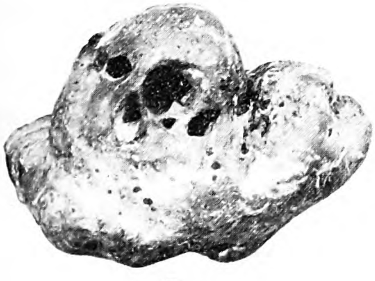

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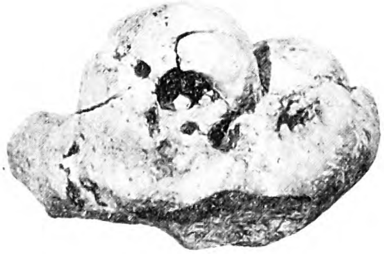

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FIGS. 1–6.—Cerebral views of periotic bones of *Aulophyseter morricei.*
(1) Left periotic, anterior process missing. Calif. Acad. Sci., Cat. No. 2796.
(2) Right periotic, posterior process missing. Calif. Acad. Sci., Cat. No. 2797,
(3) Right periotic, accessory ossicle removed. U. S. Nat. Mus., Cat. No. 11230.
(4) Right periotic, accessory ossicle attached. Calif. Acad. Sci., Cat. No. 2794.
(5) Right periotic, accessory ossicle attached. Calif. Acad. Sci., Cat. No. 2795.
(6) Right periotic, accessory ossicle attached. U. S. Nat. Mus., Cat. No. 10. 853.

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# II

# FOSSIL PINNIPEDS FROM CALIFORNIA

By REMINGTON KELLOGG

With eight figures

# FOSSIL PINNIPEDS FROM CALIFORNIA

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By Remington Kellogg

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The present contribution deals with portions of the skull of a fossil pinniped which were found in the sea cliff near the city of Santa Cruz, California, in an area mapped as Pleistocene terrace deposits in the folio[1] published by the United States Geological Survey, but lithological considerations according to E. L. Furlong indicate that the exposures are a part of the Santa Margarita formation. Two distinct types of pinnipeds are now known for the time interval represented by the Santa Margarita formation. One type, represented by a fragmentary mandible[2] found in the white clayey sands near the northwest end of the Tejon hills, between Comanche and Tejon Creeks, in Kern County, California, belongs with the true seals. The other, represented by the material hereinafter described, belongs to the group of pinnipeds which are commonly known as the eared seals (Otariidae). The position and arrangement of the bones as found suggest that the animal was moved about by ocean currents and that the skull was separated from the skeleton before the ligaments which connect the lower jaws with the skull disintegrated. A detailed study of the skulls of living pinnipeds does not seem to offer any suggestion as to the true affinities of this fossil species to existing genera of otarids.

This fossil otarid agrees with *Eumetopias* in: (1) the position and relation of the angle with respect to the condyle; (2) the shape of the mandible as a whole, particularly the production of the inferior border at the level of the posterior end of the symphysis; (3) the number of cheek teeth; and (4) the position and extent of the masseteric fossa.

These mandibles differ from those of *Allodesmus*[3] in that the latter have: (1) a much longer horizontal ramus; (2) a longer and less obliquely truncated chin; (3) a long and narrow symphysis which terminates in front of the fourth premolar; (4) mental foramina in the same general location as in *Eumetopias;* and (5) relatively smaller cheek teeth.

### Dusignathus[4] santacruzensis, genus and species new

*Type specimen*—Cat. No. 27121, Museum of Palaeontology, University of California. The material consists of the right mandible with 4 premolar teeth in place, the left mandible with 3 premolar teeth in place, the extremity of the right side of the rostrum with 2 teeth in place, a portion of the right squamosal and its zygomatic process, together with the adjoining auditory region, fragments from the supraoccipital region of the braincase, the left upper canine, the right and left lower canines, the right second upper premolar, and two large incisor teeth without crowns.

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[1] Santa Cruz Folio, No. 163, U. S. Geol. Surv.

[2] R. Kellogg, Univ. Calif. Publ., Bull. Dept. Geol. Sci., Berkeley, vol. 13, No. 4, 45. Apr. 14, 1922.

[3] R. Kellogg, *idem*, p. 26, text-figs. 1a, 1b.

[4] *δυσις*, setting of the sun, i. e., western; *γνάθος*, jaw.

*Type locality*—Sea cliff at a point between Seabright, a suburb of the city of Santa Cruz, and the light house, Santa Cruz County, California. Near latitude 36° 58′ North and longitude 122° West, Santa Cruz Folio, No. 163, U. S. Geological Survey.

*Horizon*—The specimen was found protruding from the face of the cliff about 4 feet above the beach sand at the base. The cliff at this locality is from 45 to 50 feet high and consists of several strata of a rather dense, fine-grained sandstone which becomes quite soft when weathered. Numerous large concretions are embedded in these sandstone layers. Some feet above, but not immediately over the spot where this specimen was found, is a long string of indurated sandstone concretions that have been broken through vertically, exposing sections of large cetacean bones. The pinniped remains were discovered by Porter Myron Chaffee and Miss Esther Proctor, and were collected for the Museum of Palaeontology by E. L. Furlong on December 28, 1924. Santa Margarita formation, Upper Miocene.

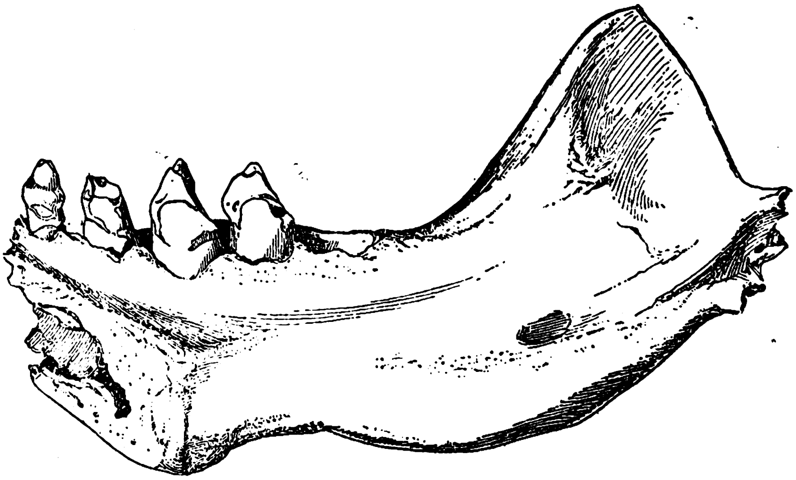

Fig. 1—Internal view of right mandible of *Dusignathus santacruzensis*, with coronoid process restored from impression in matrix. Cat. No. 27121, Mus. Palaeont., Univ. Calif.

The bones when first uncovered were soft and portions of them were completely disintegrated. Both mandibles are incomplete and the destruction of some of the missing parts may date back a long time geologically. Some of these imperfections may be attributed to imperfect fossilization, while others were of more recent occurrence and were the result of erosion or accidents when collected. Fortunately the impressions of some of the missing portions of the mandibles were distinct enough to permit restoration with plaster of Paris before the bones were completely freed from the matrix. In case of the right mandible a triangular section of the outer surface, coextensive with the three middle cheek teeth, was destroyed by decay or dissolution of the bone.

Curiously enough the mandibles of this fossil pinniped present a strange mixture of characters usually thought diagnostic of the Otariidae on one hand and the Cystophorinae on the other. The resemblance to the Cystophorinae, especially *Mirounga*, appears to be superficial. The peculiarities of the mandible, the zygomatic process, and the auditory region indicate that this extinct pinniped is very closely allied to the existing Otariidae though in some respects it is more generalized.

In brief, the mandible of this fossil pinniped seems to be characterized by the extent of the symphysis, the position of the angle, the shape of the coronoid process and the peculiarities of the cheek teeth. Unfortunately the anterior extremities of both mandibles are missing, hence one can not determine whether or not the full complement of incisors was retained and the stage of reduction represented.

In comparison to *Eumetopias*, the mandibles are short, relatively deep, but less massive. The right mandible as shown in figure 1 is incomplete, the anterior extremity of the horizontal ramus, the condyle and a portion of the coronoid process having been destroyed. The left mandible as shown in figure 2 lacks the anterior extremity, the condyle, the angle and most of the coronoid process. The horizontal ramus of the mandible is quite massive, but the coronoid process is exceedingly thin. Viewed from the side, it is at once apparent that the horizontal and ascending rami of the mandible are less curved than in *Mirounga*, the chin slopes much more abruptly, and the inferior border is produced at the level of the posterior end of the symphysis. The extero-lateral surface of the horizontal ramus is slightly convex. Three medium-sized mental foramina open on the external surface below Pm$\bar{1}$, Pm$\bar{2}$, and Pm$\bar{3}$, respectively.

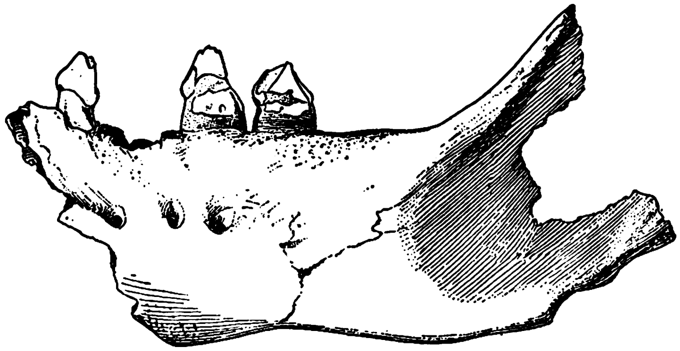

Fig. 2—External view of left mandible of *Dusignathus santacruzensis*. Cat. No. 27121, Mus. Palaeont., Univ. Calif.

The chin is obliquely truncated and the horizontal ramus is produced inferiorly at the level of the posterior end of the symphysis as in *Eumetopias*. The symphysis may be described as affording a firm cartilaginous contact for the opposing surfaces of the mandibles, rhomboidal in outline and not very deeply corrugated. As to the extent of the symphysis—the resemblance appears to be closer to *Mirounga* than to *Eumetopias*. In *Eumetopias* the symphysis terminates anterior to the second premolar, in *Mirounga* it terminates at the level of the fourth premolar, and in this fossil species at the level of the middle of the third premolar. The anterior extremity of the mandible is similar in so far as it is preserved and when complete probably exhibited a much closer resemblance to that of *Eumetopias* than it does in its present condition.

The coronoid process is exceedingly thin and is similar in shape and proportions to that of *Eumetopias*. The slope of the superior margin of the ascending ramus and its continuation—the coronoid process—is more abrupt than in *Eumetopias*. In this respect also it is quite different from the mandible of *Mirounga* in which the coronoid process is feebly developed, but the ascending ramus has assumed unusual proportions and, as a consequence thereof, the superior margin curves gradually upward. In case of *Mirounga*, the distance from the molar tooth to the extremity of the coronoid is more than twice the length of the cheek-tooth row. In this fossil jaw, however, the distance from the last molar to the extremity of the coronoid is about equal to the length of the cheek-tooth row. The coronoid process of this fossil mandible is rather wide at the base. The masseteric fossa (or coronoid fossa) is rather large, well developed and of moderate depth, with its lower border considerably below the level of the condyle. The curvature of the inferior margin of the ramus from the angle to a point near the level of the mandibular dental foramen is quite different from that of *Eumetopias* and in this respect is more like that of *Mirounga*. The angle is placed high up on the ascending ramus, in close proximity to the condyle, and this in turn is a modification which characterizes most of the Otariidae. This angular process is narrow, projecting slightly backward, but with its main axis directed inward. The inferior border of the angle (ramial tuberosity) is short and not inflected. The inferior border of the horizontal ramus curves inward, while that below the coronoid process curves outward. The condyle is largely destroyed, but seems to have been similar in shape to that of *Eumetopias*. The orifice of the mandibular dental foramen appears on the internal face of the ramus near the level of the junction of the horizontal and ascending portions of the inferior profile.

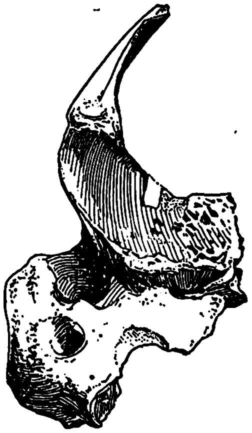

Fig. 3—Ventral view of squamosal and mastoid regions from right side of skull of *Dusignathus santacruzensis*. Cat. No. 27121, Mus. Palaeont., Univ. Calif.

When the opposing symphysial surfaces are placed in their normal relation with one another, the posterior divergence of the mandible is seen to be very great. This divergence denotes a broadening of the skull in the glenoid region, and the effect of this expansion in turn may be reflected in the modifications observed in the shape and direction of the zygomatic process. The basal portion of the squamosal bone, which gives origin to the slender attenuated zygomatic process, is thick and porous, but the ascending portion, which meets the parietal edge to edge on the lateral wall of the braincase, is relatively thin. The thin zygomatic process projects outward and forward, and is compressed from side to side anteriorly. It was under-ridden by the slender process of the jugal which extends backward as far as the anterior margin of the glenoid fossa. In this fossil the contact between the zygomatic process of the squamosal and the jugal is quite different from that of either *Mirounga* or *Cystophora*, but it does agree with the type of arch present in the living Otariidae. In the living Cytophorinae, the zygomatic process of the squamosal curves strongly upward, meeting the jugal in a more or less vertical sinuate suture and forming an enlargement superiorly. The glenoid articular surface on the squamosal of this fossil pinniped skull is wide transversely and narrow antero-posteriorly, but the anterior and posterior margins of this fossa do not overroll enough to interlock with the condyle of the mandible.

The otic and mastoid regions (fig. 3) agree more closely with the condition in the Otariidae than with that in the Cystophorinae. The stylomastoid foramen is ovoidal in outline, with a maximum diameter of 8 mm., and looks downward and outward. As regards its position, this foramen agrees more closely with *Zalophus* than with *Eumetopias*. In the matter of shape the mastoid bone also is more like that of *Zalophus*. The external auditory meatus is a large funnel-shaped orifice which opens outward immediately behind the postglenoid process of the squamosal. The petrous portion of the auditory region is largely destroyed and portions of the structures associated with the vestibule are exposed to view.

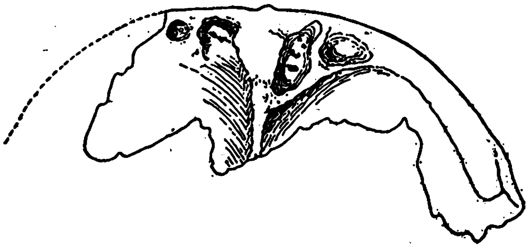

Fig. 4—Upper portion of supraoccipital bone of *Dusignathus santacruzensis*. Cat. No. 27121, Mus. Palaeont., Univ. Calif.

Among the fragments of this skull is a portion of the top of the braincase (fig. 4), measuring 93 mm. in width and 50 mm. in length. It comprises the apex of the supraoccipital and the postero-superior extremities of the parietals. This fragment is important for it shows that a well-developed sagittal crest was present. Judging from the posterior end, the sagittal crest was more like that of *Eumetopias* than that of *Zalophus*. The top of the braincase appears to have been rather broad, somewhat similar to that of *Eumetopias*, and the lateral curvature of the dorsal surface of the parietal is rather gradual.

On each side of the vertical carina on the superior portion of the supraoccipital are several pits or rugosities for the insertion of muscles. The lambdoid crest is not prominent and is not developed to the same degree as in old individuals of *Zalophus* and *Eumetopias*.

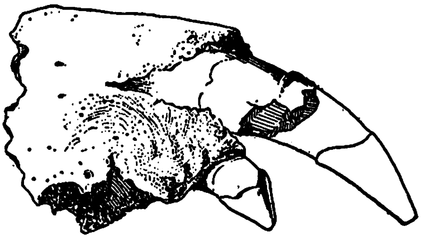

Fig. 5—Fragment from right side of rostrum of *Dusignathus santacruzensis*. Cat. No. 27121, Mus. Palaeont., Univ. Calif.

A distal fragment of the right side of the rostrum (fig. 5) preserved with the above described remains is similar in general shape and proportions to *Eumetopias*, but the cheek teeth are much larger, whereas the canine is actually less robust. It is fairly certain that the skull of this fossil pinniped had a short rostrum, similar in its proportions to that of *Eumetopias*. The superior margin of the maxilla anterior to the level of the nasals slopes abruptly to the external incisor as it does in *Eumetopias*, while in *Mirounga* the slope is decidedly more gradual. The maxilla is quite deep at the level of the canine. The curvature of the base of the enamel crown as well as the inclination of the incisor show that the inferior margin of the maxilla curved strongly upward across the root of this tooth, paralleling conditions in *Eumetopias*, and differing in this respect from the skull of *Mirounga*. Anteriorly the maxilla is a thick porous bone in conformity with the large size of the roots of the canine and the anterior cheek teeth.

The root of the large canine measures 67.5 mm. in length, and its greatest transverse diameter is approximately 22 mm. The apex of the enamel crown is missing, but otherwise it is complete. The first upper premolar has a rather robust root and the enamel crown on the inside measures 18.3 mm. in height. The apex of the crown of this tooth is missing and the base is damaged more extensively in front than behind. The antero-posterior diameter of the crown at the base is at least 14.5 mm. The crown of the first premolar is compressed from side to side, convex externally and concave internally, and with a faint vertical carina on the anterior border. The enamel surfaces of all the teeth are smooth, highly polished and without any trace of nodosities. A large alveolus for the second upper premolar and a large nutrient canal posterior to it, which leads to the extremity of the root of the canine, are exposed to view. A second upper premolar tooth which fits in this alveolus lacks the extremity of the root and most of the enamel on the inner face of the crown is missing. Practically all of the teeth were fractured in one or more places and portions of them were lost.

In *Mirounga* all of the cheek teeth are anterior to the base of the jugal, while in *Eumetopias* not more than 3 of the 6 cheek teeth are situated in front of the anterior end of the jugal.

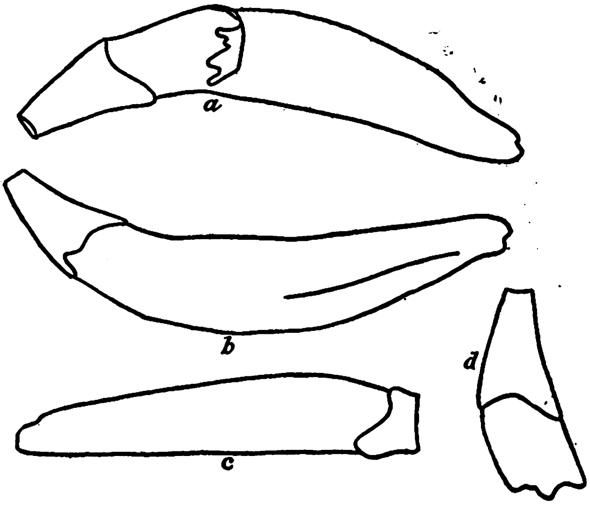

FIG. 6.—Canine teeth of *Dusignathus santacruzensis*. (*a*) External view of left upper canine. (*b*) Internal view of left upper canine. (*c*) External view, left lower canine. (*d*) External view of distal end of right upper canine. Cat. No. 27121, Mus. Paleont., Univ. Calif.

Even more puzzling than the question of the exact relationship of this fossil pinniped to living genera of otarids is the type of crown possessed by the cheek teeth. In their present condition one can not determine definitely whether or not accessory cusps were present. One molar, four premolars and a large canine were present as in *Eumetopias*, but whereas the mandible is shorter and relatively deeper than in the latter, the cheek teeth are actually larger. The alveolus for the root of the large canine extends backward and terminates below the third premolar. Without doubt the thinness of the enamel is in some measure responsible for the present condition of the crowns of all the teeth associated with this specimen. Not one of these teeth has a perfect crown and the enamel is highly polished. The apices of all the cheek teeth are missing and patches of enamel and cement of varying sizes have either been sheared off or worn off from their bases at the anterior and posterior angles.

The canines curve from the extremity of the root to the apex of the crown, and near the middle the roots are subovate in cross-section. The crowns of the canines are high, compressed from side to side, and are without any trace of a vertical carina on their anterior and posterior surfaces. The best preserved (figs. 6, *a* and *b*) of the four canines belonging to this specimen measures 105 mm. in length and when the crown was complete the tooth probably measured 110 mm. The outer surface of the enamel crown (fig. 6*a*) is considerably worn, for there is a narrow incomplete border some 62 mm. from the extremity of the root, although the unworn portion of the crown is at least 78 mm. distant from the extremity. The greatest depth of the unworn portion of the crown is 55 mm. The pulp cavity of the canines is completely closed. As seen in cross-section the teeth consist of an internal stalk of ossified pulp and dentine which is covered externally by a thin layer of cement, apparently nowhere exceeding 2 mm. in thickness.

*Measurements of the mandibles and teeth (in millimeters)*

| | Right | Left |
|---|---|---|
| Length of mandible as preserved | 212.5 | 167.5 |
| Depth of mandible at posterior end of symphysis | 60.5 | 56.2 |
| Depth of mandible at level of alveolus for molar | 54.8 | 53.8 |
| Distance from posterior margin of alveolus for molar to anterior margin of alveolus for first premolar | 91.3 | 85 |
| Anteroposterior diameter of alveolus for first lower premolar | 12.5 | 10.4 |
| Anteroposterior diameter of alveolus for second lower premolar | 15.2 | 16.8 |
| Anteroposterior diameter of alveolus for third lower premolar | 18.8 | 18.2 |
| Anteroposterior diameter of alveolus for fourth lower premolar | 18.8 | 17.4 |
| Anteroposterior diameter of alveolus for first lower molar | 17± | 16.3 |
| Greatest length of symphysis | 74+ | 73.6+ |
| Anteroposterior diameter of crown of first lower premolar | 11.4 | 11.5 |
| Transverse diameter of crown of first lower premolar | 10.8 | 10.3 |
| Transverse diameter of crown of second lower premolar | 13.8 | x |
| Transverse diameter of crown of third lower premolar | 11.7+ | 11.2 |
| Anteroposterior diameter of crown of fourth lower premolar | 19 | 17.2+ |
| Transverse diameter of crown of fourth lower premolar | 12.2 | 12+ |

Limb bones of two other species of fossil pinnipeds have been submitted to the writer for study and description by E. L. Furlong, curator of the Museum of Palaeontology of the University of California. It is probable that these bones belong to undescribed pinnipeds, but it does not appear advisable to propose new names for such scanty material. Attention is called herewith to their occurrence and it is hoped that additional material will be obtained at these localities. The writer is indebted to Professor Chester Stock of the California Institute of Technology for information in regard to the occurrence of this specimen.

### Zalophus, species ?

*Specimen*—Cat. No. 24255, Right radius, Museum of Palaeontology, University of California.

*Occurrence*—From the lumber yard (Arnold's locality)[1] at northeast end of the town of San Pedro, Los Angeles County, California. Near latitude 33° 44′ 58″ North and longitude 118° 16′ 44″ West, hill 48, Wilmington Quadrangle, U. S. Geol. Surv. Locality No. 2047, Museum of Palaeontology.

*Horizon*—This radius was collected by Dr. Loye H. Miller in November 1923, in the littoral horizon of the Upper San Pedro formation from which bones of land mammals and birds have been obtained. Pleistocene.

The California sea lion (*Zalophus californianus*) appears to be the nearest living relative of this fossil pinniped, both in the point of size and in its structural peculiarities in so far as they are revealed by the radius. Briefly stated this fossil radius differs from those of *Zalophus* in that: (1) an elongate depression is present on the posterior surface of the shaft, presumably for the insertion of the interosseous ligament (2) the distal two-thirds of the shaft is considerably broader and the lower anterior border is nearly straight; (3) the ulnar facet on the head is grooved transversely on its posterior face; (4) the facet for the capitulum of the humerus is relatively longer and the facet for the trochlea of the humerus is proportionately smaller; and (5) the bicipital tuberosity on the neck is occupied by a longitudinal rugose depression for the brachialis anticus muscle. The relative importance of one or all of these differences may be a matter of personal opinion, but in the writer's estimate they are worthy of at least specific distinction, and these coupled with the other differences hereinafter set forth may characterize the radius of this Pleistocene species of *Zalophus.*

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[1] R. Arnold, The Palaeontology and stratigraphy of the marine Pliocene and Pleistocene of San Pedro, California, Mem. Calif. Acad. Sci., vol. 3, 27 et seq., 1903.

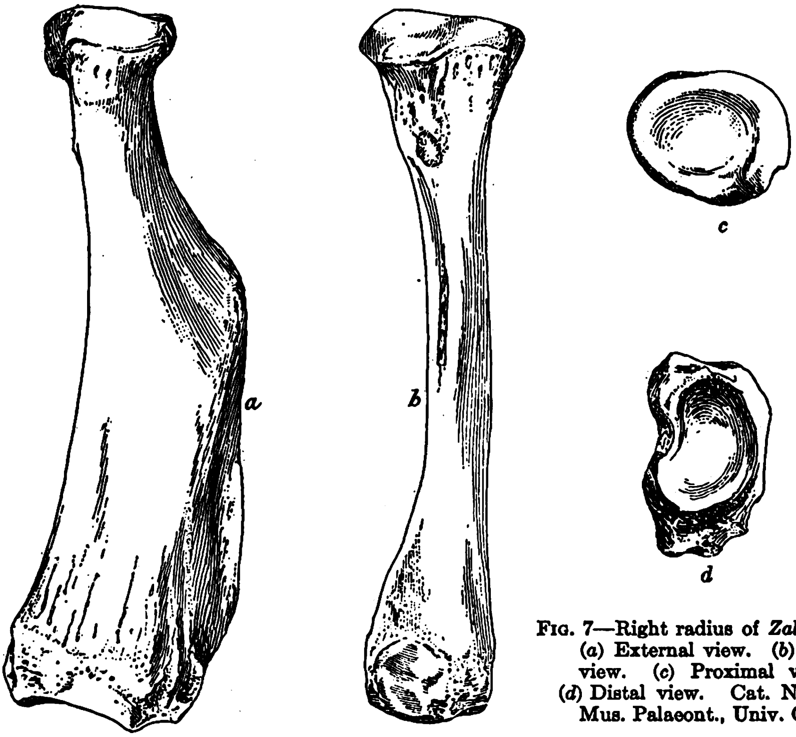

FIG. 7—Right radius of *Zalophus* sp. (*a*) External view. (*b*) Posterior view. (*c*) Proximal view. (*d*) Distal view. Cat. No. 24255, Mus. Palaeont., Univ. Calif.

The proximal extremity or head of this fossil radius is damaged on its anterior border. It is provided with a shallow concave surface, similar in outline to that of *Zalophus*, for articulation with the capitulum of the humerus. The circumference of the head is smooth, and the curvature and extent of this surface is comparable to the same portion of the corresponding bones of *Zalophus californianus* and *Eumetopias jubata.* On the postero-internal angle the circumference is much broader and displays an ulnar articular surface, slightly grooved in a transverse direction on the posterior face which, when in position, rolls in the lesser sigmoid cavity of the ulna. The shaft is constricted below the head, forming a neck, and the overhang of the head is greatest on the internal and anterior sides. The bicipital tuberosity is located on the posterior face of the shaft near the postero-internal angle, its superior margin terminating 14 mm. below the inferior margin of the ulnar facet. It would seem that the branchialis anticus muscle finds attachment in the elongate rugose depression on the bicipital tuberosity itself, while the biceps ends in an adjoining depression on the posterior face of the shaft, paralleling conditions in *Zalophus*.

The shaft is bowed outward as in other otarids and is broadest distally. Between the neck and the level of the usual area of insertion of the Pronator radii teres, the shaft expands rather rapidly and becomes strongly compressed from side to side. These modifications give rise to the anterior thin-edged crest which extends from the insertion of the Pronator radii teres to the groove for the tendons leading to the thumb on the distal end of the shaft. The external surface of the shaft may be described as convex and the internal surface as concave. On the posterior surface of the shaft, beginning at the level of the upper margin of the insertion of the Pronator radii teres and extending distally for a distance of 27 mm., is a rather narrow and deep depression presumably for the insertion of the interosseous ligament, paralleling conditions in *Arctocephalus alascanus* and *Eumetopias jubata,* and differing in this respect from that of *Zalophus* on which there is no trace of a corresponding depression. Distal to this depression the posterior face of the shaft gradually widens and forms a distinct interosseous crest on the postero-internal margin above the epiphysis. The facet on the posterior face of the distal epiphysis for articulation with the corresponding surface on the ulna is similar in shape to the type of facet found in living otarids. The groove for the tendons of the thumb, which crosses the anterior border of the distal epiphysis, is not as deep as that on the radius of *Zalopthus* and the styloid process is less prominent.

The distal extremity of the radius, with its carpal articular surface, which is strongly concave from before backward and less so from side to side, bears a close resemblance to the corresponding epiphyses of *Zalophus* and *Arctocephalus.* For measurements of this radius, see table on page 36.

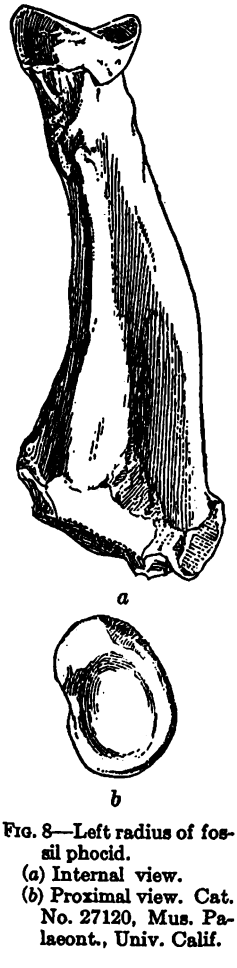

**Fig. 8—Left radius of fossil phocid.**
**(a) Internal view.**
**(b) Proximal view. Cat. No. 27120, Mus. Palaeont., Univ. Calif.**

### Phocid, (?) genus and species

*Specimen*—Cat. No. 27120, Left radius. Museum of Palaeontology, University of California.

*Occurrence*—Upper San Leandro Dam Project, in pit No. 2, situated 0.25 mile north of San Leandro Creek and 0.25 mile west of Miller Creek, near town of Hayward, Alameda County, California. Southwest ¼ of section 9, township 2 S., range 2 W., Concord Quadrangle or San Francisco Folio, No. 193, U. S. Geol. Surv.

*Horizon*—This radius was collected by C. D. Bates and A. Borland, during March 1926, in the Hambre or Oursan sandstone, Temblor formation, Middle Miocene.

The reasons for stating that the pinniped to which this fossil radius belonged should be referred to the family Phocidae rather than to the family Otariidae are as follows: (1) the neck is long and rather stout; (2) not more than the distal half of the shaft is expanded; and (3) the Pronator radii teres is inserted below the middle of the shaft.

This fossil radius is badly crushed, especially above the distal epiphysis, and consequently the anterior face is somewhat distorted. The proximal end of the radius is suboval in outline and the facet for articulation with the capitulum of the humerus occupies most of the proximal surface; this facet is strongly concave and slopes from the internal to the external margin of the head. This facet is continuous antero-internally with the sloping articular surface for the trochlea of the humerus. The circumference of the head is irregular in outline and the smooth border is deepest on the internal and posterior faces. The ulnar facet is not set off from the smooth adjoining surface of the circumference by distinct margins. In general form the head of this fossil radius is quite unlike previously described fossil phocid radii. The overhang of the head is most pronounced on the internal face and the neck is strongly depressed between the bicipital tuberosity and the lower border of the smooth circumference of the head. The bicipital tuberosity is situated on the postero-internal angle of the shaft about 12 mm. below the circumference of the head; it is irregular in outline and rugose for the attachment of muscles. The bicipital tuberosity is flattened and the areas for the insertion of the biceps and brachialis anticus muscles are not defined very clearly.

*Measurements of the radii (in millimeters)*

| | *Zalophus* sp., No. 24255, Univ. Calif. Right radius | *Zalophus californianus* No. 16296, U. S. N. M. Left radius | *Eumetopias jubata* No. 21523, U. S. N. M. Right radius | *Arctocephalus alascanus* No. 23331, U. S. N. M. Right radius | *Mirounga angustirostris* No. 21890, U. S. N. M. Right radius | Fossil phocid No. 27120, Univ. Calif. Left radius |
|---|---|---|---|---|---|---|
| Greatest length of shaft............ | 194.9 | 196 | 224.6 | 178.5 | 202.8 | 151.4 |
| Greatest transverse diameter of head of radius......... | 35 | 40 | 41.9 | 28.7 | 37.5 | 30 |
| Greatest extero-internal diameter of head of radius.. | 42.7 | 44 | 49.3 | 35.8 | 42 | 43 |
| Greatest transverse diameter of distal end of radius...... | 54.1 | 54 | 67.5 | 44.4 | 58.7 | 52.5 |
| Greatest extero-internal diameter distal end of radius | 33 | 31.7 | 38.2 | 29.2 | 31.8 | 29+ |
| Distance from proximal angle of anterior border above insertion of Pronator radii teres to distal facet....... | 130 | 125.5 | 147.8 | 116.2 | 119.6 | 75.4 |
| Greatest width of shaft at level of insertion of Pronator radii teres..... | 43.5 | 35.5 | 49 | 31.6 | 40 | 33.2 |
| Greatest transverse diameter of facet for carpal on distal end of shaft....... | 33.7 | 33 | 43.9 | 26.4 | 40.3 | 30.5 |

The whole shaft is compressed from side to side and in its present condition is more twisted than it is bowed outward. The distance from the proximal margin of the head to the upper margin of the insertion of the Pronator radii teres is about equal to the distance from the latter point to the distal margin of the styloid process. The rugose area for the insertion of the Pronator radii teres is at least 30 mm. in length and is placed on the external border of the anterior face. The thin-edged crest at the distal end of the anterior face of the shaft is relatively short, and the groove for the tendons leading to the thumb cross over to the internal face above the distal epiphysis.

The internal and external faces of the distal end of the shaft, as mentioned above, are crushed together above the epiphysis, but it is evident that the external surface originally was convex and the internal concave. There is a small rugose area on the posterior face of the shaft, for the most part above the level of the insertion of the Pronator radii teres, for the insertion of the interosseous ligament. Below this rugose area, the posterior face of the shaft narrows somewhat and then widens again at the distal end. In contrast to the radius of the fossil *Zalophus*, the interosseous crest is formed on the postero-external margin. The facet on the posterior face of the distal epiphysis for articulation with the corresponding facet on the ulna slopes obliquely from its upper margin to the carpal articular surface.

The oval facet on the distal epiphysis for articulation with the carpal bone is rather large and deeply concave. The internal surface of the distal epiphysis and the corresponding border of the carpal facet are missing. The styloid process is large and projects below the level of the posterior margin of the carpal facet.

### III

# A HYAENARCTID BEAR FROM THE LATER TERTIARY OF THE JOHN DAY BASIN OF OREGON

By JOHN C. MERRIAM and CHESTER STOCK

1 Plate

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# A HYAENARCTID BEAR FROM THE LATER TERTIARY OF THE JOHN DAY BASIN OF OREGON

By John C. Merriam and Chester Stock

## INTRODUCTION

In the course of field investigations on the Mascall and Rattlesnake deposits and faunas of the John Day Basin of eastern Oregon, conducted by Chester Stock and C. L. Moody during 1916,[1] fragmentary material of a hyaenarctid type was discovered at University of California collecting locality 3042. The specimen was described in 1925 by John C. Merriam, Chester Stock and C. L. Moody.

Locality 3042 was visited again during the summer of 1926. Charles W. Merriam, a member of the party in search of mammalian remains at this locality, discovered several hyaenarctid teeth and fragments. Study of this new material has shown that it represents the individual found in 1916. The additional remains furnish valuable information relating to the Tertiary bears of North America.

## LOCATION OF MATERIAL

The locality (U. C. C. locality 3042) at which the hyaenarctid remains were found is that at which a number of interesting specimens have been obtained by expeditions from the University of California in 1900 and 1916. At this station there have been secured a number of specimens of *Hipparion*, belonging to forms related to the species *H. sinclairi* and *H. occidentale*.

Locality 3042 occurs near the lower boundary of the NW¼ and NE¼ of Sec. 36, T. 12S., R. 25E., Willamette Base and Meridian. The locality is situated on the south slope of a ridge with elevation of 3240 feet, shown on the topographic map known as the Picture Gorge Special, Oregon, soon to be published by the U. S. Geological Survey, and is approximately 3 miles southwest of the Mascall Ranch.

The south face of the 3,240 foot-ridge at locality 3042 presents exposures of white tuffaceous sediments overlain by coarse gravels and brownish tuffs or clays. The deposits appear at first sight to represent two distinct accumulations, heretofore presumed to be the Mascall Miocene at the bottom of the exposed section and the Rattlesnake Pliocene at the top. The tentative view has been entertained that the presumed Mascall deposits represent a higher horizon than that occurring at the type section of the Mascall, near the Mascall Ranch.

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[1] Carnegie Inst. Wash. Pub. No. 347, pp. 65–66, fig. 17, 1925.

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Further investigation of the geologic relations of the later Tertiary formations at this locality and in the adjacent area by John P. Buwalda has cast some doubt upon the original assumption. There appears to be a possibility that in the section under consideration the separation of the lower and the upper beds is more apparent than real and that the entire section exposed at locality 3042 may be Rattlesnake in age. The lower portion of the section may represent the Rattlesnake formation, although differing somewhat in its lithological characters from the typical Rattlesnake. In view of the fact that a study of the geology and palaeontology of the Picture Gorge sheet is now in progress it does not appear desirable to express a definite opinion as to the age of the deposits at locality 3042 until the critical studies in the field have been concluded.

## HISTORY OF DISCOVERY AND IDENTIFICATION OF MATERIAL

The hyaenarctid material found by Stock and Moody at locality 3042 in 1916 consisted of a maxillary fragment with a carnassial tooth and the alveolus for $P\underline{3}$, and a root of a molar tooth, No. 22461, University of California Collection. $P\underline{4}$ lacked a portion of the protocone. The specimens discovered by Charles W. Merriam in 1926 included $M\underline{1}$ and $M\underline{2}$ and several fragments of teeth. In each case the specimens were found lying on the white tuffaceous sediments distinctly below the brownish beds with coarse gravels which are exposed in the upper portion of the section. There is reason for believing that the teeth were originally embedded in the white deposits.

The preservation of the remains found in 1926 corresponds almost exactly to that of the material collected in 1916. When the upper carnassial and associated material secured by Stock and Moody and the upper molars and fragments of teeth discovered by Charles W. Merriam were brought together, it was found that the outer anterior root, broken away and missing in $M\underline{1}$ secured in 1926, had been collected with the carnassial in 1916. The root fits to $M\underline{1}$ perfectly. Furthermore, a fragment of crown in the collection made by Charles W. Merriam was identified as a portion of the protocone missing in the carnassial collected by Stock and Moody. The fragment fits perfectly in position below the root supporting this cusp in $P\underline{4}$.

Recognition of a missing part of the specimen collected in 1926 in the collections secured in 1916 and the identification of a fragment of a tooth crown found during the past summer as a part belonging to the carnassial collected ten years ago leave no doubt that the teeth were obtained from the same spot and that they are parts of the same individual. The fact that the characteristics of the two upper molars and of the fourth upper premolar were before their comparison suggested to indicate the same type of animal, and that more careful study shows the same relationship, gives every reason for considering these teeth as representing the same individual.

As a result of the study of the material secured in 1916 the form occurring at locality 3042 was tentatively referred to the Ursidae and was presumed to be a member of the *Indarctos-Hyaenarctos* group.

## DESCRIPTION OF MATERIAL

### Indarctos, near oregonensis Merriam, Stock and Moody

(Plate I)

**Carnegie Inst. Wash. Pub. No. 347, pp. 65–66, fig. 17, 1925.**

P$\underline{4}$, as described by Merriam, Stock and Moody, resembles *Indarctos oregonensis* in its general characters, but differed in the somewhat smaller size of the protocone and in the different form of the parastyle. The tooth is also smaller and less massive than in the type of *I. oregonensis*. The parastyle in P$\underline{4}$ of the type of *I. oregonensis* seems to have been more distinctly separated from the paracone and is probably more nearly conical in shape. With the discovery of the missing part of the protocone (deuterocone) in P$\underline{4}$, the size of this cusp relative to the size of the tooth is seen to be quite comparable to that in the carnassial of *I. oregonensis*.

In other respects P$\underline{4}$ in No. 22461 is distinctly of the type of *Indarctos oregonensis* and differs from *Arctotherium* in that the protocone (deuterocone) is situated in advance of the cleft between paracone and metacone, and its anterior border extends as far forward as the cleft between paracone and parastyle. In *Arctotherium* the protocone is situated much farther back and its anterior border reaches only slightly in advance of the cleft between paracone and metacone.

Of the two molar teeth found by Charles W. Merriam, M$\underline{1}$ is of the *Hyaenarctos* type with high, relatively simple and laterally slightly compressed paracone and metacone and with simple protocone and hypocone. There is no division of the protocone or hypocone as in *Arctotherium* and there are no accessory tubercles in the middle of the occlusal surface. There is a faint tubercle on the cingulum in front of the paracone suggesting an incipient parastyle as in *Arctotherium*, but it is not more strongly marked than in certain other bears. The inner anterior border of the crown tends to make this end of the tooth rather angular and prominent, in which respect No. 22461 is like the California species of *Arctotherium*. M$\underline{1}$ is 3-rooted as in *Arctotherium simum*. The largest root supports the inner side. Of the two outer roots that supporting the metacone is the larger.

M$\underline{1}$ is narrower transversely than in any species of *Hyaenarctos* known to the writers. The dimensions are most nearly approached in *Indarctos* (*Hyaenarctos*) *punjabiensis* Lydekker. The proportions of M$\underline{1}$ approach in some respects those of *Arctotherium haplodon* or of the corresponding tooth in *Tremarctos*.

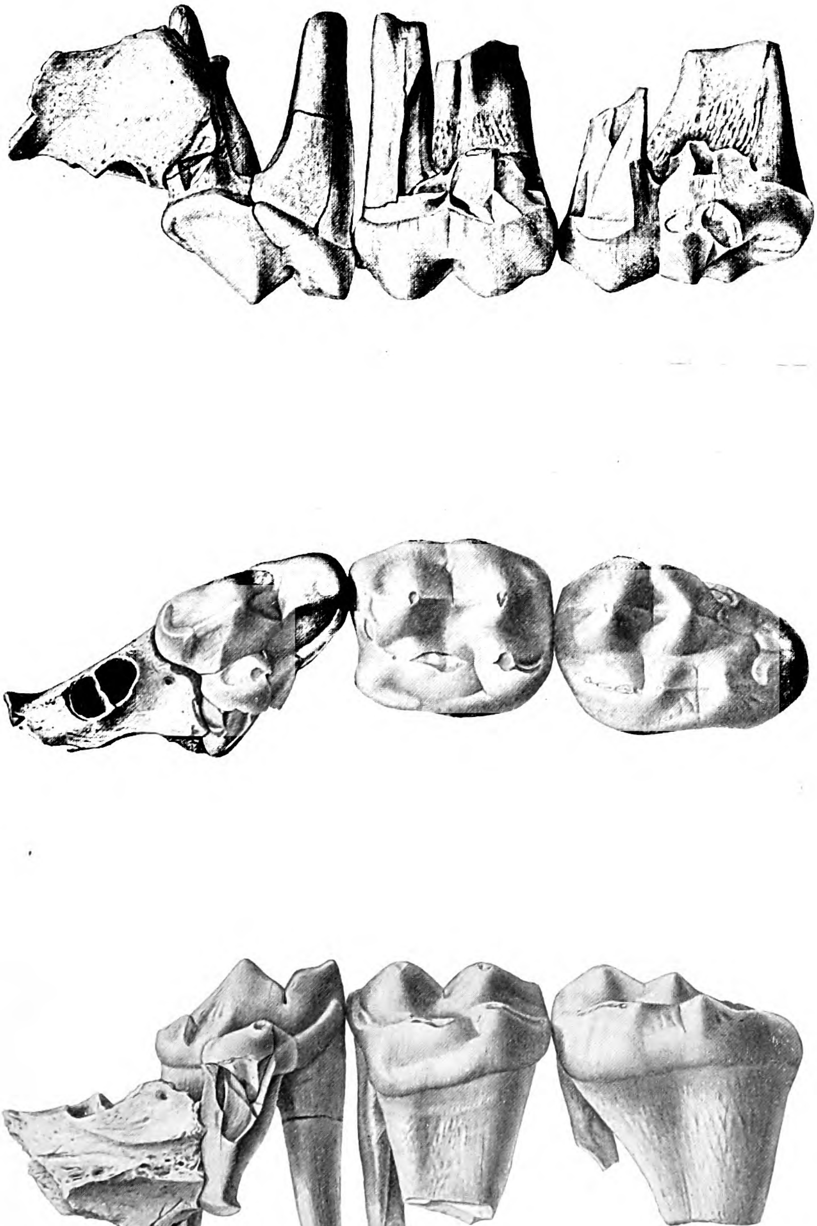
M$\underline{2}$ corresponds more nearly to the structure of *Indarctos oregonensis* than to any other of the forms in the *Hyaenarctos* group. It approaches in certain respects the characters of *Arctotherium*, especially in the size of the heel. On the whole, however, the characters are those of *Hyaenarctos* rather than of *Arctotherium* as indicated by the lower cusps and the absence of intermediary cusps or corrugations and the general simplicity of the occlusal surface of the tooth. M$\underline{2}$ is 3-rooted, with the roots comparable in size to those in *I. oregonensis*. The two outer roots are separated slightly more than in the latter form.

M$\underline{2}$ is smaller than in the type of *Indarctos oregonensis*. It is also relatively narrower and the heel seems larger. M$\underline{2}$ in No. 22461 may show a little less narrowing across the metacone than in the type of *Indarctos oregonensis*. The narrowing of the heel region is also less marked in No. 22461 than in the type of *Indarctos oregonensis.* The development of the heel in No. 22461 approaches that of the arctotheres and of the fairly specialized bears of the *Ursus* group. The stage of development of this character is unlike that in any other member of the *Hyaenarctos* group. The only comparable form in this group of the old world is *Indarctos salmontanus* Pilgrim of the Salt Range.

No. 22461 represents an individual of the *Indarctos-Hyaenarctos* group. It is probably the most highly specialized member of the group thus far known.

*Measurements of No. 22461*

| | *mm.* |
|---|---|
| P$\underline{4}$, anteroposterior diameter measured along outer side | 26.7 |
| P$\underline{4}$, width across protocone | 19.3 |
| P$\underline{4}$, anteroposterior diameter of paracone at base | 13 |
| M$\underline{1}$, greatest anteroposterior diameter | 26.7 |
| M$\underline{1}$, greatest transverse diameter | 22.9 |
| M$\underline{2}$, greatest anteroposterior diameter | 32.4 |
| M$\underline{2}$, anterior end of tooth to posterior end of paracone | 12.6 |
| M$\underline{2}$, anterior end of tooth to middle of metacone | 17.4 |
| M$\underline{2}$, width of tooth across paracone (approximate) | 23.6 |
| M$\underline{2}$, width of tooth across metacone | 22 |



*Indarctos*, near *oregonensis*, Merriam, Stock and Moody. Superior teeth, No. 22461 U. C. C. Outer, occlusal and inner views, ×1.0. Rattlesnake Pliocene or Mascall Miocene, John Day Basin, eastern Oregon.

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## IV

# GEOLOGY AND PALAEONTOLOGY OF THE CROOKED RIVER BASIN, WITH SPECIAL REFERENCE TO THE BRIDGE CREEK FLORA

By RALPH W. CHANEY

**With twenty plates and four text-figures**

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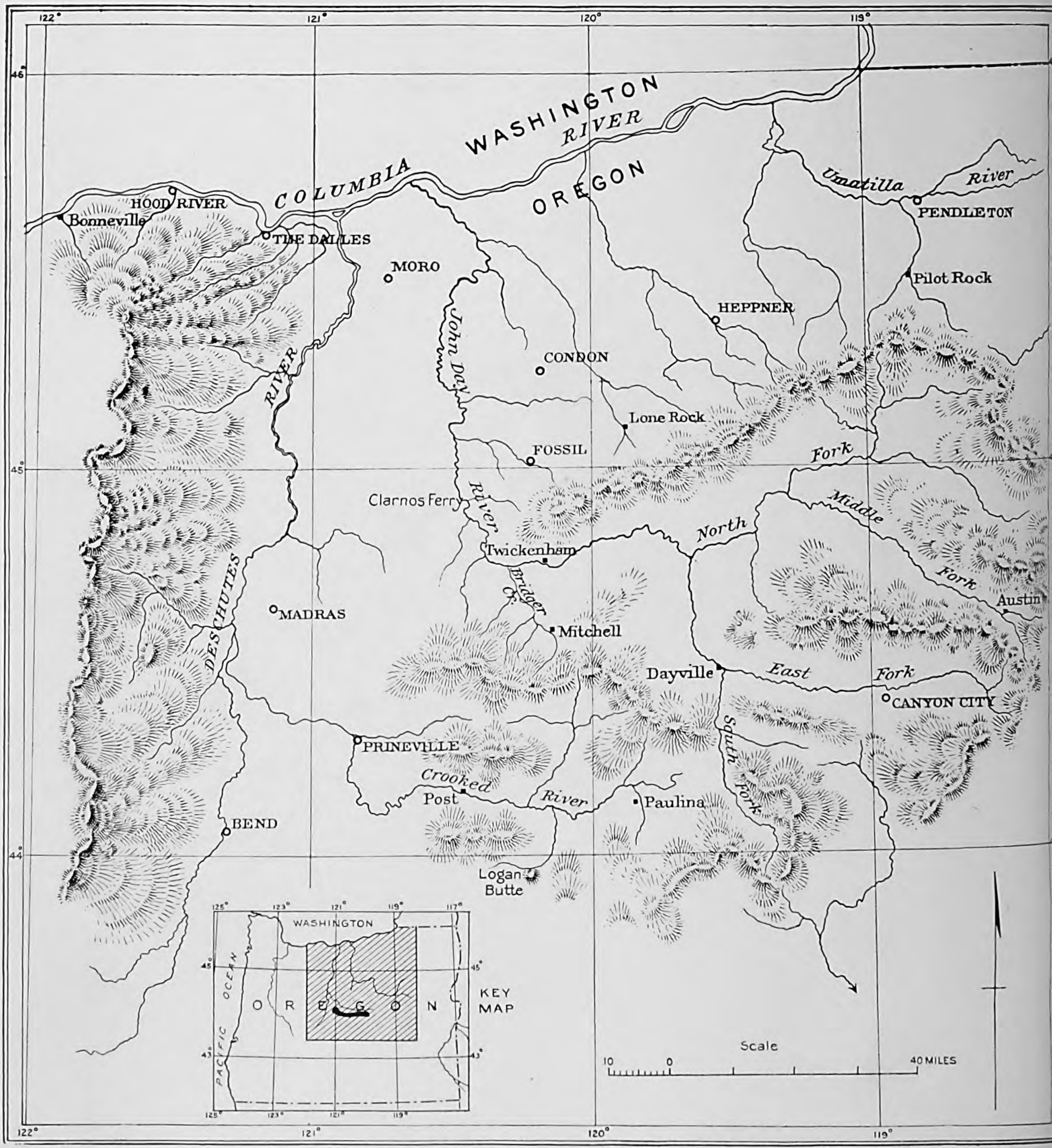

MAP OF NORTH CENTRAL OREGON

# GEOLOGY AND PALAEONTOLOGY OF THE CROOKED RIVER BASIN, WITH SPECIAL REFERENCE TO THE BRIDGE CREEK FLORA

By Ralph W. Chaney

## INTRODUCTION

The Tertiary floras of eastern Oregon rank high in importance among those in western North America, due to their central location and to the comparatively complete geologic sequence of the rocks with which they are associated. They are commonly represented by well-preserved material occurring in volcanic shales, which split readily along the bedding planes and as a result an abundance of usable material is available.

Since 1920 the writer has been engaged in a study of these floras, during the first two years under the auspices of the Department of Palaeontology of the University of California, and more recently under those of the Carnegie Institution of Washington. The work has centered in the John Day Basin because of its complete section and its abundance of well-preserved fossil material, and preliminary statements of results have already been published.[1] The Crooked River Basin lying about 40 miles distant on the south side of the Blue Mountains has been visited on a number of occasions, and its well-displayed stratigraphic column and abundant fossil plant remains have thrown much light on the problems of the John Day Basin. This paper will discuss the fossil floras of the Crooked River Basin, together with a brief statement of their geologic occurrence.

Most of the collections of fossil plants were made in 1921 with the assistance of R. J. Russell, and in 1922 with the assistance of R. H. Seashore. H. L. Mason assisted in the quantitative studies and collecting of 1926. On other occasions the writer has visited the region with J. C. Merriam, E. L. Furlong, C. Stock and J. P. Buwalda, whose assistance in the preparation of this paper is acknowledged. Valuable suggestions as to the petrographic characters of the igneous rocks have been given by N. L. Taliaferro.

Few published references have been made to the geology and palaeontology of the Crooked River Basin. The first mention of this region known to me is by Thomas Condon in an unpublished letter to

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[1] Chaney, Quantitative Studies of the Bridge Creek Flora, Am. Jour. Sci., vol. VIII, pp. 127–144, 1924; I: A Comparative Study of the Bridge Creek Flora and the Modern Redwood Forest; II: The Mascall Flora—Its Distribution and Climatic Relation. Carnegie Inst. Wash. Pub. No. 349, 1925.

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J. S. Newberry dated August 20, 1869, now in the possession of the New York Botanical Garden; he writes:

> "I succeeded this trip in connecting the rocks of the Crooked River with those of the John Days, extending over a strip of country 100 miles across. Three rocky systems I found the same over this stretch of country."

These appear to represent the Clarno formation, the John Day series and the Columbia Lavas, and his correlations were correct. He found no plant fossils here other than "sparsely silicified wood."

In his *Contribution to the Geology of the John Day Basin*, which represents the first complete and accurate statement of the geology and palaeontology of that region, Merriam quotes Osmont as stating the occurrence of the John Day series at Logan Butte, but makes no mention of their occurrence along the Crooked River to the North.[1] He also mentions, on Osmont's authority, the occurrence of Columbia lava, Mascall formation and Rattlesnake formation in the Crooked River region.[2] In a later discussion of *The Tertiary Faunas of the John Day Region*, by Merriam and Sinclair, mention is made of a caniniform premolar of a Merycoidodont from the Mascall beds on the divide between Camp Creek and Crooked River.[3]

In his report on *The Geology and Water Resources of Central Oregon*,[4] Russell describes the upper and lower ends of the Crooked River drainage, but appears not to have visited much of the area here under discussion. He describes the section at Logan Butte, mentioning Merriam's statement of the presence of the John Day Series there, and refers to the tuffs underlying the lava rim near Prineville. His description of the drainage, climate and vegetation of central Oregon is of particular interest.

A comparatively recent report by Stock and Furlong[5] describes the occurrence of John Day beds at Logan Butte, from which marsupial remains and other vertebrate fossils have been collected.

The only other references to the Crooked River Basin are by the writer—an abstract in which the preliminary results of his work there are set forth,[6] and a mention of the occurrence of the Lower John Day beds at the Gray Ranch in a discussion of the Bridge Creek flora.[7]

The Crooked River flows west along the south side of the Blue Mountains,[8] turning north and entering the DesChutes River about 30 miles northwest of Prineville. As shown by the map (plate 1), these streams have a right-angled course similar to that of the John Day

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[1] Merriam, Univ. Calif., Bull. Dept. Geol., vol. 2, No. 9, 297–298, 1901.

[2] Merriam, *op. cit.*, 305 and 311.

[3] Merriam and Sinclair, Univ. Calif., Bull. Dept. Geol., vol. 5, No. 11, 196, 1907.

[4] I. C. Russell, U. S. Geol. Surv., Bull. 252, 1905.

[5] Stock and Furlong, Univ. Cal., Bull. Dept. Geol., vol. 13, No. 8, 312, 1922.

[6] Bull. Geol. Soc. Am., vol. 34, p. 129, 1923.

[7] Carnegie Inst. Wash. Pub. No. 349, p. 21, 1925.

[8] A westward extension of the Blue Mountains proper, sometimes termed the Strawberry Range.

River at the north, the change in direction in each case being due apparently to intervening westward spurs of the Blue Mountains. The Crooked River Basin, as the term is used here, includes that portion of the stream from Prineville east to Paulina.

In the upper part of its course, where the Crooked River passes through the relatively non-resistant tuffs of the Clarno formation, the John Day Series and the Mascall formation, its valley is comparatively straight and averages several miles in width. Only where the volcanic rocks of the Clarno formation become dominant, and in the short basalt gorge some 15 miles east of Post, does the valley become narrow. About 22 miles upstream from Prineville the river turns northward into a deep and narrow gorge cut into the Columbia Lava. Its course here is very crooked, with a series of right-angled turns, evidently related to major lines of weakness in the massive basalt flows which lie at the base of the canyon walls. Five miles above Prineville the river again cuts through the basalt, which here forms conspicuous cappings on the buttes, and has widened out its valley in the soft John Day tuffs. Few tributaries enter the Crooked River between Post and Prineville and none is of large size.

The area, including the Crooked River Basin as well as the John Day Basin and many other fossil localities, is commonly referred to as eastern Oregon, because of its position to the east of the Cascade Mountains, which form the principal climatic and topographic boundary of the state. As shown by the map (plate 1), all of this area is actually in the north central part of Oregon.

## GENERAL GEOLOGIC FEATURES

No attempt has been made to carry on a detailed study of the geologic relations of the Crooked River Basin. Observations have been made in connection with the work on the fossil floras and are included here subject to the corrections which future detailed studies will make possible. The observed section is as follows:

Rattlesnake formation (?)—Tuff, ash and rhyolite.
Mascall formation—Tuff and ash. Fossil vertebrates.
Columbia Lava—Basalt flows.
John Day Series—Tuff, ash, shale and rhyolite. Fossil plants and vertebrates.
Clarno formation—Tuff, ash, conglomerate and several types of lavas. Fossil plants.

Farther to the east, in the vicinity of Suplee, a Cretaceous fauna has recently been collected by Packard, and Palaeozoic beds have been observed.

The structure and stratigraphy is most readily studied along the highway from Prineville to Paulina, the easternmost point visited by the writer. For most of this distance, totaling about 80 miles, the highway follows the Crooked River.

## STRUCTURAL FEATURES

The Crooked River has cut its way across an anticline whose axis lies about 20 miles southeast of Prineville and whose limbs extend nearly to Prineville on the one side and beyond Paulina on the other. The axis has a general north-south direction, trending from a few degrees east of north to a few degrees west of south. As seen along the Crooked River Highway south and east from Prineville, the flows of Columbia Lava dip to the west and north at an angle of 2°; 22.5 miles from Prineville they pass above river level and the John Day Series is exposed for a distance of about 2 miles along the river. The road here runs mostly along the strike, and the beds are seen to be dipping westward at an angle of about 8°. The underlying Clarno formation is first encountered about 25 miles from Prineville, where the beds dip some 5° toward the west. Near the Riverside Ranch, which lies about 34 miles from Prineville by the River Highway, the dip increases to 15° to 25°, in a direction slightly north of west. The axis of the structure is not far from here, as the dip shortly changes to east, being 9° east at a point 2 miles east of the bridge near the old Post store. The Clarno extends for about 25 miles eastward along the Crooked River, with numerous small flexures, dipping under the John Day Series at road level on the Gray Ranch, some 50 miles by highway from Prineville. The John Day Series dips eastward at an average angle of 10°, passing under the Columbia Lava within 2 miles. The Columbia Lava forms a gorge about a mile in length, and dipping below river level is overlain with apparent structural unconformity by the Mascall and Rattlesnake (?) formations. These dip away to the eastward at an angle of about 3°, with several low folds and faults of small displacement.

In the structure and distribution of these two younger formations, particularly the uppermost Rattlesnake (?), there is some suggestion of two periods of folding which may correspond more or less closely to those in the John Day Basin. Near Picture Gorge the steeply inclined Mascall formation and Columbia Lava are overlain by Rattlesnake beds dipping only about 5°, indicating a post-Mascall uplift of considerable amount followed by erosion, deposition of the Rattlesnake formation and a post-Rattlesnake folding of a comparatively small order. In the Crooked River Basin, at the east end of the anticline as above noted, the Mascall and Rattlesnake (?) formation dip gently off to the east, resting against the Columbia Lava which appears to dip eastward at a considerably higher angle. The Rattlesnake (?) formation overlaps on to the John Day beds, resting upon their upturned edges at the Gray Ranch, and at Reams Ranch and

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Logan Butte to the south. If these overlapping rhyolites are correctly interpreted as representing the Rattlesnake and are not, as is a possibility, flows of rhyolite within the John Day Series, there is not only evidence of a post-Columbia Lava and pre-Mascall period of major folding, but also an indication of a considerably wider extent of the Rattlesnake flows than of the underlying Mascall tuffs. In the case of the flows at Logan Butte, the section given by Russell indicates the presence of associated rhyolitic tuffs and conglomerates which rather definitely indicate their Rattlesnake age, as suggested in this connection by Osmont.[1]

## STRATIGRAPHY

Only the general aspects of the stratigraphy will be considered at this point. The important details concerning the relations of the Clarno formation and the John Day Series will be taken up in connection with the discussion of the floras from these formations.

### THE CLARNO FORMATION

This formation as here defined includes the dominantly volcanic portion of the Clarno formation as described by Merriam.[2] The so-called Upper Clarno, which includes the Bridge Creek leaf shales of the John Day Basin, and which is also represented in the Crooked River Basin, is referred to the Lower division of the John Day Series for reasons which will be fully discussed below. The base of the Clarno has not been certainly recognized in the region studied, but it may be supposed to rest on Cretaceous sediments which are known to outcrop to the east, at Suplee. It is possible that the dark-colored sedimentary material in the road cut just west of the Gray Ranch gate represents Cretaceous beds, in which case the upper surface of the Cretaceous must be considered to have been an irregular one.

The Clarno formation is made up largely of volcanic rocks. Basic lavas are conspicuous, and the light-colored pumiceous tuff layers which characterize this formation in the John Day Basin are also present, though they are less extensively exposed than at the type locality near Clarnos Ferry.

On the Riverside Ranch some 18 miles southeast of Prineville (34 miles by the River Highway), fossil leaves occur in thin seams of ash associated with massive layers of grayish-brown tuff, near the base of the formation; the species noted are for the most part included in the flora from the Clarno formation at Cherry Creek and elsewhere in the John Day Basin. Farther up in the section green and gray tuffs predominate; these are for the most part very coarse and are commonly agglomeratic; they are eroded to form pinnacles which are characteristic of this formation in the John Day Basin. Associated with these tuffs and comprising the most conspicuous outcrops, are intrusions and flows of basaltic lavas; it seems possible that some of the intrusions may have taken place during the subsequent volcanic activities incidental to the outpouring of the Columbia Lava, but most of them may be considered to be of Clarno age.

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[1] Russell, *op. cit.*, p. 60, letter of J. C. Merriam.

[2] Univ. Calif. Bull. Dept. Geol., vol. 2, No. 9, 285, 1901.

The large dike 23 miles up the highway from Prineville, which will be described below in connection with the discussion of the Columbia Lava, may possibly be of Clarno age. As yet the rock making up this dike has not been examined at close range, and its reference to the Columbia Lava is made provisionally because of its general resemblance to basalt and its apparent continuity with the overlying basaltic flows at the top of the canyon. However, the lava on the hill east of the dike is rhyolitic and it is possible that the dike itself is made up of rhyolite; in this case its age is probably Clarno.

Near the top of the Clarno, reddish tuffs are conspicuous, associated with yellowish calcareous tuffs and agglomerates and with basic lavas. The reddish tuffs are fine textured as compared with the rest of the Clarno, but are much coarser than the volcanic shales and tuffs of the overlying John Day Series. They can be further distinguished from the brick-red shales of the Lower John Day by their more purplish color on weathered surfaces, by the abundance of pumice and by their erosion to form comparatively high and rocky hills and ridges. The total observed thickness of the Clarno formation is at least 1,000 feet, and may be as much as 1,500 feet.

While the Clarno formation is regularly overlain by the John Day Series, basalt which appears to be referable to the Columbia Lava rests upon it at several places. About 20 miles by highway from Prineville, on the north side of the river, a hill of Clarno tuff projects up some 400 feet into the Columbia Lava which makes up the walls of the gorge for many miles along this part of the course of the Crooked River. The tuff is commonly red along its contact with the basalt, and is intruded by at least 3 dikes, one of which is not less than 50 feet across. The Clarno is distinctly bowed at the top, as though pushed up by these intrusions. Overlying it and connected with these dikes are several flows of basalt which reach an aggregate thickness of 100 feet, and which extend continuously to the east and west along the rim of the gorge. Again at a point 17 miles farther upstream (37 miles from Prineville on the highway), the Clarno is overlain by some 50 feet of basalt which is probably referable to the Columbia Lava.

There is evidence of an erosional unconformity between the Clarno and the John Day Series, which overlies it at all points observed except those above noted. On the Gray Ranch, 50 miles up the river from Prineville, the Lower John Day beds rest upon a Clarno surface which had been extensively eroded prior to their deposition. A diagram

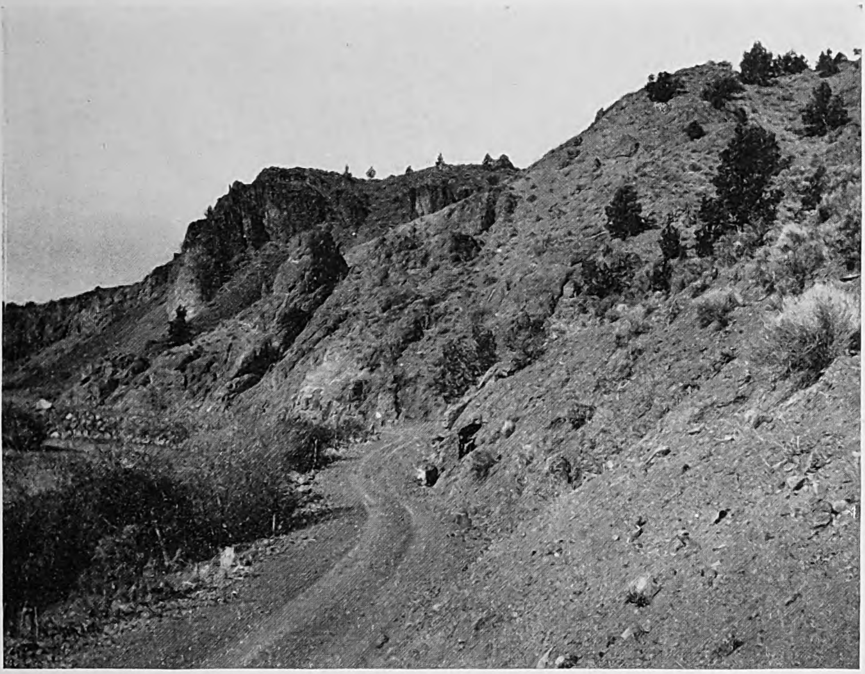

FIG. 1—Clarno formation in valley of Crooked River, 32 miles above Prineville. Basic intrusions in coarse gray agglomerate

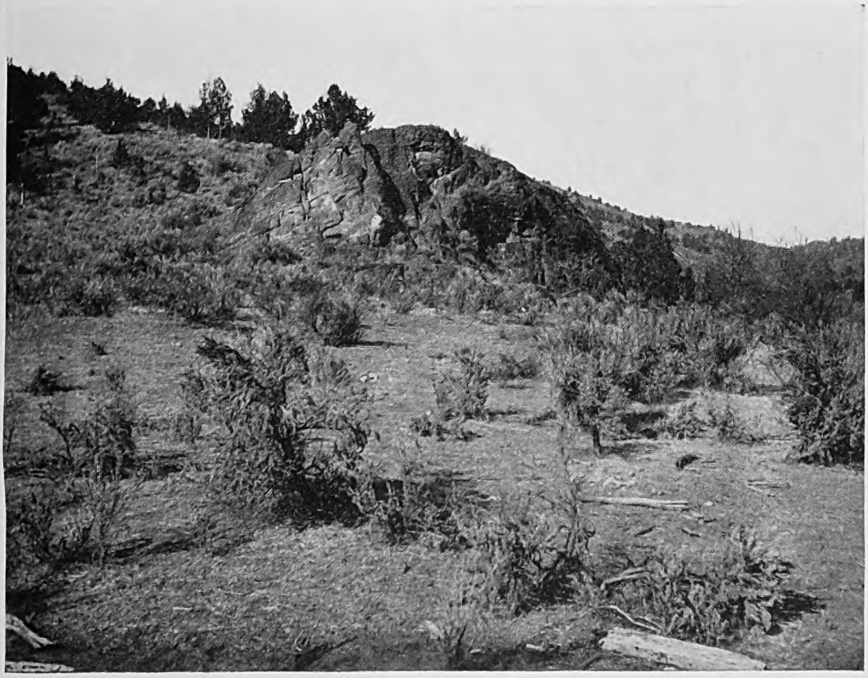

FIG. 2—Fossil Locality 3945 in the Clarno at Riverside Ranch. Living vegetation is largely *Juniperus occidentalis* and *Artemesia tridentata*

characteristic of this formation in the John Day Basin. Associated with these tuffs and comprising the most conspicuous outcrops, are intrusions and flows of basaltic lavas; it seems possible that some of the intrusions may have taken place during the subsequent volcanic activities incidental to the outpouring of the Columbia Lava, but most of them may be considered to be of Clarno age.

The large dike 23 miles up the highway from Prineville, which will be described below in connection with the discussion of the Columbia Lava, may possibly be of Clarno age. As yet the rock making up this dike has not been examined at close range, and its reference to the Columbia Lava is made provisionally because of its general resemblance to basalt and its apparent continuity with the overlying basaltic flows at the top of the canyon. However, the lava on the hill east of the dike is rhyolitic and it is possible that the dike itself is made up of rhyolite; in this case its age is probably Clarno.

Near the top of the Clarno, reddish tuffs are conspicuous, associated with yellowish calcareous tuffs and agglomerates and with basic lavas. The reddish tuffs are fine textured as compared with the rest of the Clarno, but are much coarser than the volcanic shales and tuffs of the overlying John Day Series. They can be further distinguished from the brick-red shales of the Lower John Day by their more purplish color on weathered surfaces, by the abundance of pumice and by their erosion to form comparatively high and rocky hills and ridges. The total observed thickness of the Clarno formation is at least 1,000 feet, and may be as much as 1,500 feet.

While the Clarno formation is regularly overlain by the John Day Series, basalt which appears to be referable to the Columbia Lava rests upon it at several places. About 20 miles by highway from Prineville, on the north side of the river, a hill of Clarno tuff projects up some 400 feet into the Columbia Lava which makes up the walls of the gorge for many miles along this part of the course of the Crooked River. The tuff is commonly red along its contact with the basalt, and is intruded by at least 3 dikes, one of which is not less than 50 feet across. The Clarno is distinctly bowed at the top, as though pushed up by these intrusions. Overlying it and connected with these dikes are several flows of basalt which reach an aggregate thickness of 100 feet, and which extend continuously to the east and west along the rim of the gorge. Again at a point 17 miles farther upstream (37 miles from Prineville on the highway), the Clarno is overlain by some 50 feet of basalt which is probably referable to the Columbia Lava.

There is evidence of an erosional unconformity between the Clarno and the John Day Series, which overlies it at all points observed except those above noted. On the Gray Ranch, 50 miles up the river from Prineville, the Lower John Day beds rest upon a Clarno surface which had been extensively eroded prior to their deposition. A diagram

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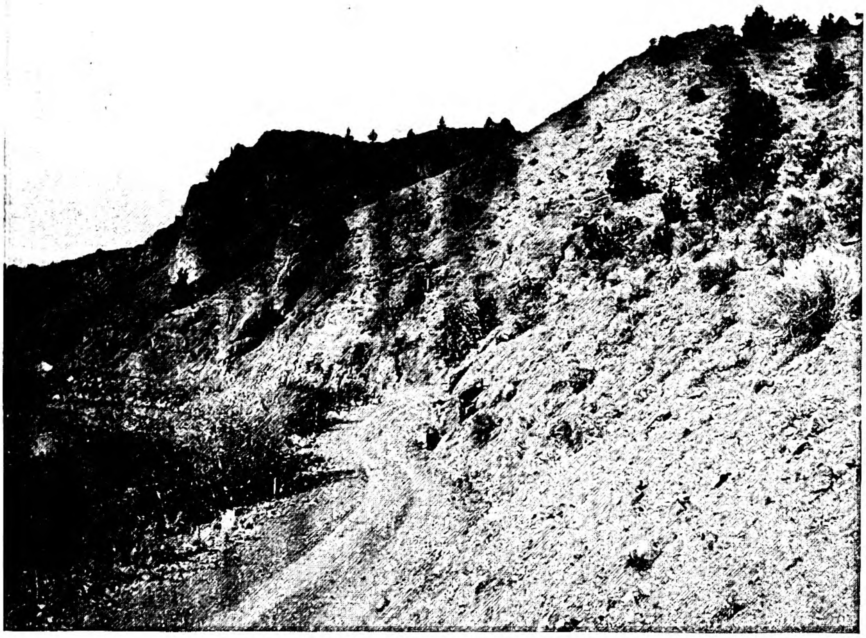

Fig. 1—Clarno formation in valley of Crooked River, 32 miles above Prineville. Basic intrusions in coarse gray agglomerate

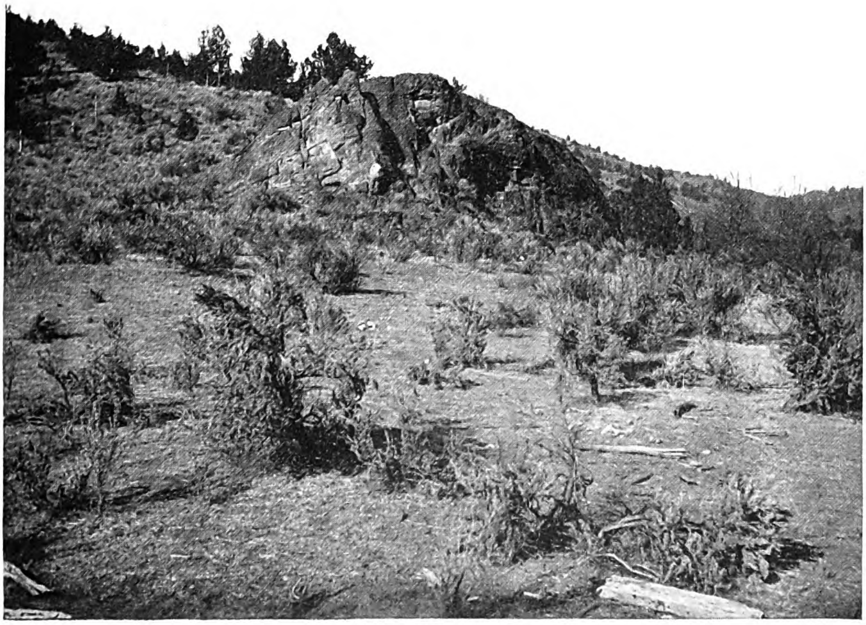

Fig. 2—Fossil Locality 3945 in the Clarno at Riverside Ranch. Living vegetation is largely *Juniperus occidentalis* and *Artemesia tridentata*

showing the stratigraphic relations of the two formations at this point is included with the discussion of the Bridge Creek flora on page 61. The leaf-bearing shales of the Lower John Day on the south side of the river near the Ream Ranch also appear to rest upon a Clarno surface of considerable relief. At the type locality of the Bridge Creek flora on Bridge Creek in the John Day Basin, the lower John Day beds appear to rest in a considerable depression in the underlying Clarno. Merriam has mentioned[1] the greater extent of the Upper beds in the John Day Basin, which is a further indication of an interval of erosion in at least part of this region preceding the laying down of the John Day Series. There appears to be wide-spread evidence that during the latter part of the Clarno epoch, erosional processes became increasingly important and developed an irregular surface on which the John Day Series was deposited.

## THE JOHN DAY SERIES

All three divisions of the John Day Series, as described by Merriam from the John Day Basin, are represented along the Crooked River. The Lower reddish beds are relatively thick, with a total of 700 feet or more; the green and white beds of the Middle and Upper divisions as exposed along the Crooked River are thinner than in the John Day Basin, the total thickness of the Series here being probably not more than 1,000 feet. At Logan Butte, some 12 miles to the south of the River and near one of its tributaries, the total thickness of the exposed part of the John Day beds is placed by Osmont at between 3,000 and 4,000 feet.[2] The Clarno formation has not been noted there.

The Bridge Creek shales of the John Day Basin have formerly been considered to represent the upper part of the Clarno formation, and to be separated from the John Day Series by an erosional unconformity. Their reference to the Clarno rather than the John Day beds was in large part due to the determination of the age of the Bridge Creek flora as Upper Eocene, which would necessarily place it definitely below the Upper Oligocene John Day Series. With the gradually developing evidence of the younger age of the Bridge Creek flora, as studied both in the John Day and the Crooked River Basins, there has been no floral basis for considering the Bridge Creek shales as older than the John Day Series. Further, in the Crooked River Basin at the Gray Ranch, the well-developed and typical section of the Lower John Day contains ash layers bearing a Bridge Creek flora throughout most of its thickness, definitely establishing the Lower John Day age of the Bridge Creek shales, both here and in the John Day Basin. Dr. Merriam has suggested, however, that since the leaf shales of the Gray Ranch extend farther up into the section than they are known to do in the John Day area, certain of the leaf horizons may be somewhat younger than at the type locality on Bridge Creek.

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[1] J. C. Merriam, Univ. Calif., Bull. Dept. Geol., vol. 2, No. 9, 298.
[2] *Op. cit.*, 298.

The Lower John Day beds are for the most part tuffaceous shales, conspicuously banded with red and yellowish white or buff and eroded to form rounded, mud-covered hills and slopes. Fragments of gypsum are locally abundant on the slopes. At the Gray Ranch locality, red shales are more conspicuous in the lower two-thirds of the section, although they occur practically to the top and in places grade laterally into the less common buff-colored beds. In the hill at the base of the section here, several layers a few inches thick, of earthy manganese dioxide, with broken tuffaceous fragments of plagioclase and lapillae, form well-defined black bands which together with the red and yellowish shales produce a rather striking effect. Similar black manganese layers occur in the Lower John Day hills on Bridge Creek in the John Day Basin. Scattered through the section at eight horizons are layers of dense white or gray ashy shale, rarely somewhat lignitic; these are commonly 2 or 3 feet in thickness and may extend laterally for as much as 125 feet, although in most cases their distribution is more limited. This shale contains large numbers of leaf impressions and fragments of silicified wood, together with a few fish and insects. As stated above, the floral assemblage is so like that of the Bridge Creek shales of the John Day Basin as to leave no question as to their being of essentially the same age.

To the east and to the south of the fossil localities on the Gray Ranch are light-colored tuffs, a hundred feet or more in thickness, which appear to be referable to the Upper John Day. On the west limb of the structure, some 25 miles up the River from Prineville, the Middle and Upper divisions of the John Day Series, with a thickness of about 300 feet, overlie the Lower red shales without apparent break. They are eroded here to form the steep gullied slopes so characteristic of these beds in the John Day Basin and at Logan Butte to the south. Although they were not examined by the writer at close range, they appear to contain an intercalated flow of rhyolite, reddish in color and similar in appearance and occurrence to the rhyolite flows along the John Day River.

At Logan Butte the Lower, Middle and possibly the Upper divisions are well developed, with a total thickness, as estimated by Osmont, of 3,000 to 4,000 feet. This region is somewhat higher than the Crooked River Basin proper, and may well have been nearer the center of volcanic activity resulting in a greater accumulation of pyroclastic material.

A considerable fauna has been collected here, mostly by Stock, including such characteristic John Day forms as oreodons, carnivores, hypertragulids and rhinoceroses, as well as a marsupial. Of these

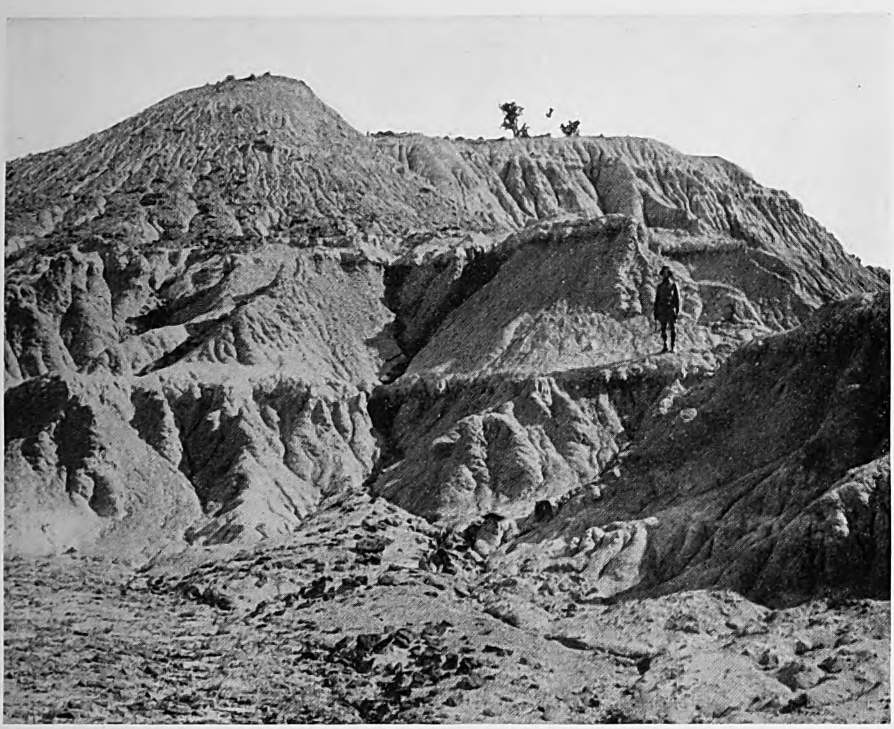

FIG. 1—Middle Division of John Day Series at Logan Butte

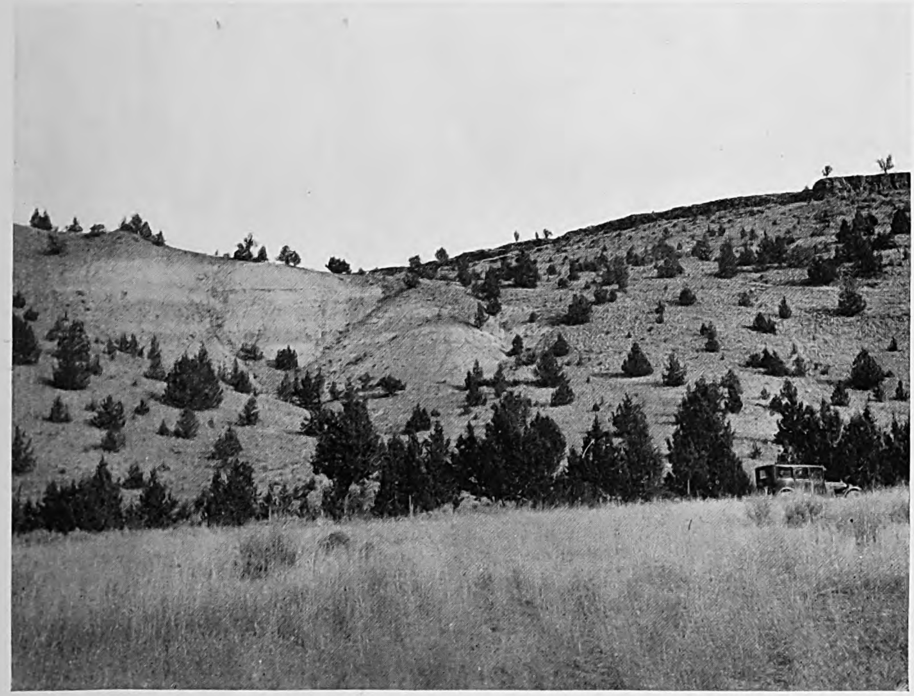

FIG. 2—Plant Locality 3947 at Brink's Ranch. Tuffs of probable Upper John Day age are overlain by basalt flows

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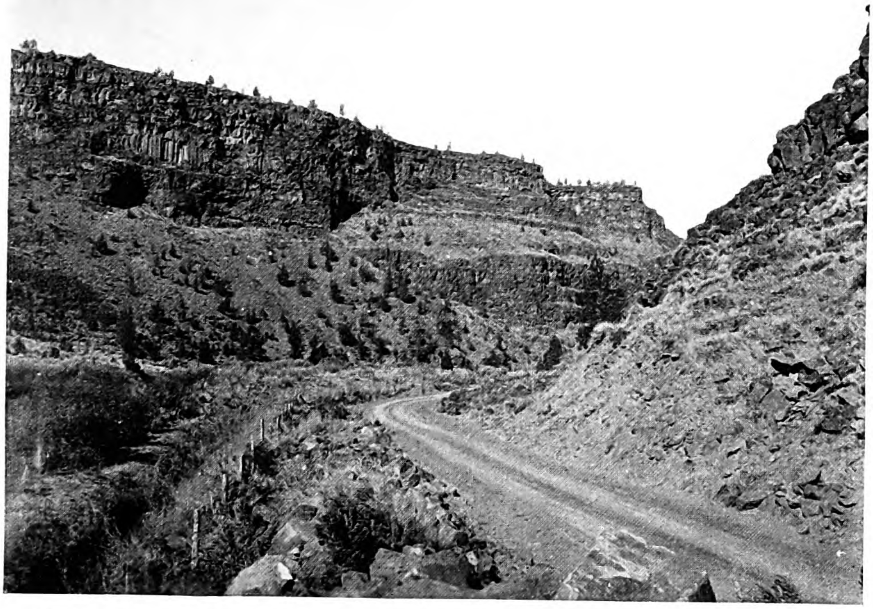

FIG. 1—Gorge of Crooked River, about 8 miles above Prineville, showing flows of Columbia Lava

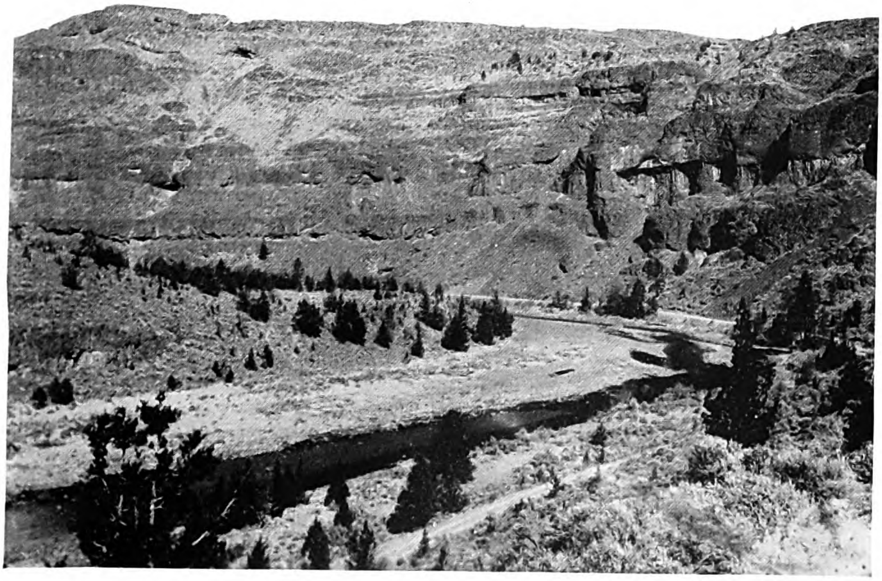

FIG. 2—Massive flows near base of Columbia Lava, 15 miles above Prineville

only the carnivores[1] and the marsupial[2] have been described. Unconformably overlying the Series here are rhyolites and rhyolitic tuffs which have been tentatively referred to the Rattlesnake formation.[3]

Certain of the lava-capped buttes within a few miles of Prineville show sections of 100 feet or more of light-colored tuff. At the Brink Ranch, 3 miles east of Prineville, more than 200 feet of tuff are exposed under the basalt rim. Several layers of ashy shale contain fragmentary leaf impressions making up an assemblage which although closely related to the Bridge Creek flora is clearly somewhat younger. A hypertraguline tooth has recently been collected here by Charles Merriam which indicates that these tuffs represent the Middle or Upper division of the John Day Series. The lithology favors their reference to the Upper division.

### THE COLUMBIA LAVA

The Crooked River has cut a gorge through the Columbia Lava from a point 15 miles southeast down nearly to Prineville. 18 to 25 flows can be distinguished above the talus, which covers the lower half of the walls of the gorge. Columnar structure is well developed at most points; in the lower part of the section where talus is not present may be seen massive flows of the type which characterizes the Columbia Lava in the Gorge of the Columbia River near Bridal Veil. About 19 miles up the River from Prineville, the flows are locally bowed up by what appear to be intrusions of basalt; these domes are about 100 feet across, and columnar structure is well developed in the lava pushed up into them (see plate 5, fig. 1).

Several dikes filling fissures which may have been sources of the Columbia Lava flows are found 23 miles up the highway from Prineville. The largest of these is nearly 1,000 feet in width and forms a ridge which may be seen to extend for 10 miles or more to the northwest and for a considerable distance to the south. This dike appears to be connected with the basalt flows overlying the John Day Series on the south side of the river. It has not been examined at close range, but is probably made up of basalt similar to these flows. The occurrence of rhyolite on the hill to the west, as noted above in the discussion of the Clarno formation, brings up the possibility that these dikes may be made up of rhyolite, in which case they would appear to be referable to the Clarno.

Twenty miles up the river from Prineville the Clarno formation is intruded and overlain by basalt, the overlying flows continuing without break into the Columbia Lava flows, making up the Crooked River gorge. About 35 miles up the river from Prineville, on the south side, basalt 50 feet or more in thickness lies almost horizontally upon the

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[1] Merriam, Univ. Calif. Bull. Dept. Geol., vol. 5, 1–64, 1907.

[2] Stock and Furlong, Univ. Calif. Bull. Dept. Geol., vol. 13, 311–317, 1921.

[3] Stock and Furlong, *op. cit.*, 312.

Clarno. In view of the opinion of certain observers that the Cascade Lavas of Recent age are represented in this region, it can not be certainly stated that this is a part of the Columbia Lava. Again in the case of the basalt capping the buttes near Prineville, there is some question as to whether these may not be Recent in age. It may be noted, however, that there is no apparent break in the continuity of the lavas from the top of the Crooked River gorge section to those capping the buttes near Prineville, and that the structure at each point is essentially the same. The lava near Prineville is an olivine basalt similar to that of the Columbia Lava. Further, as above noted, the lower portion of the Prineville buttes is made up of John Day tuffs, containing characteristic plant and animal remains. The writer has not yet recognized any basalt flows younger than Miocene in the Crooked River Basin.

The Columbia Lava as exposed in the gorge on the west limb of the Crooked River anticline reaches a thickness of at least 1,000 feet; to the east of the Gray Ranch on the east limb, its thickness is probably much less. It rests upon an eroded surface which is especially conspicuous where it is in contact with the Clarno formation.

## THE MASCALL FORMATION

Some 55 miles up the Crooked River from Prineville and overlying the Columbia Lava, there are several hundred feet of light-colored, fine-grained tuffs which are lithologically similar to the Mascall formation as exposed in the John Day Basin near Dayville. No fossils have been found by the writer in these deposits, but Merriam and Sinclair mention the collecting of a caniniform tooth of a small Merycoidodont by Osmont and Davis on the divide between Camp Creek and Crooked River, probably not far from Logan Butte.[1] An exposure near Paulina which has not been closely examined shows the white color characterizing the diatomaceous shales which are common near the base of the Mascall in the John Day Basin. Future work may disclose the presence of other vertebrate remains as well as fossil plants.

## THE RATTLESNAKE (?) FORMATION

Overlying the Mascall beds is a series of rhyolitic tuffs and rhyolite which closely resembles the Rattlesnake formation of the John Day Basin. Above the Maury schoolhouse, some 60 miles up the river from Prineville, the following section has been noted:

| | *Feet* |
|---|---|
| Reddish tuff (at top) | 8 |
| Ryolite in thin flows | 18 |
| Gray sandy tuff with pumice | 6 |
| Talus | |

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[1] Merriam and Sinclair, *op. cit.*, 196.

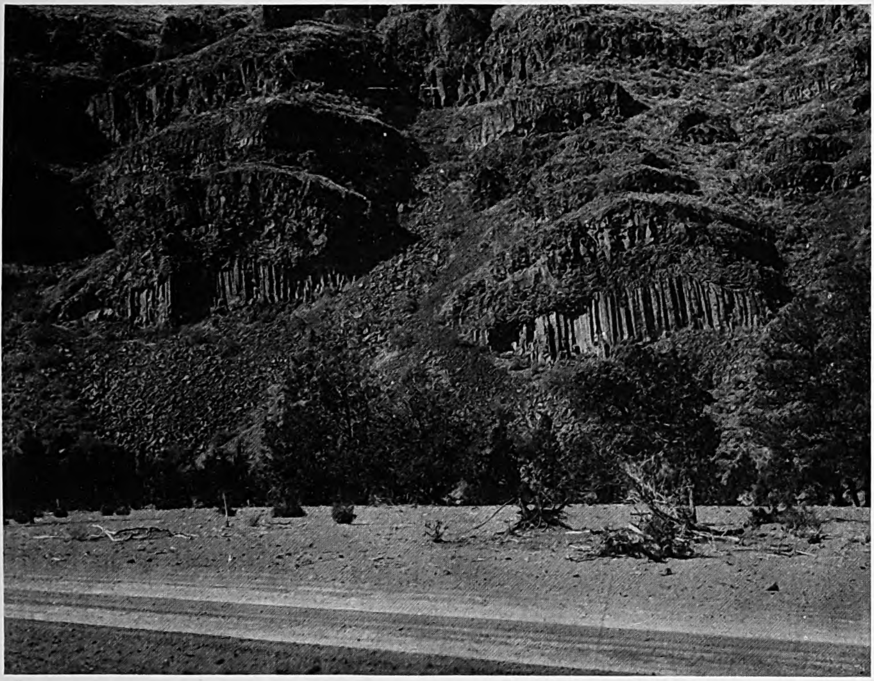

FIG. 1—Columbia Lava in gorge of Crooked River, 19 miles above Prineville, showing domes which appear to result from intrusions within basalt

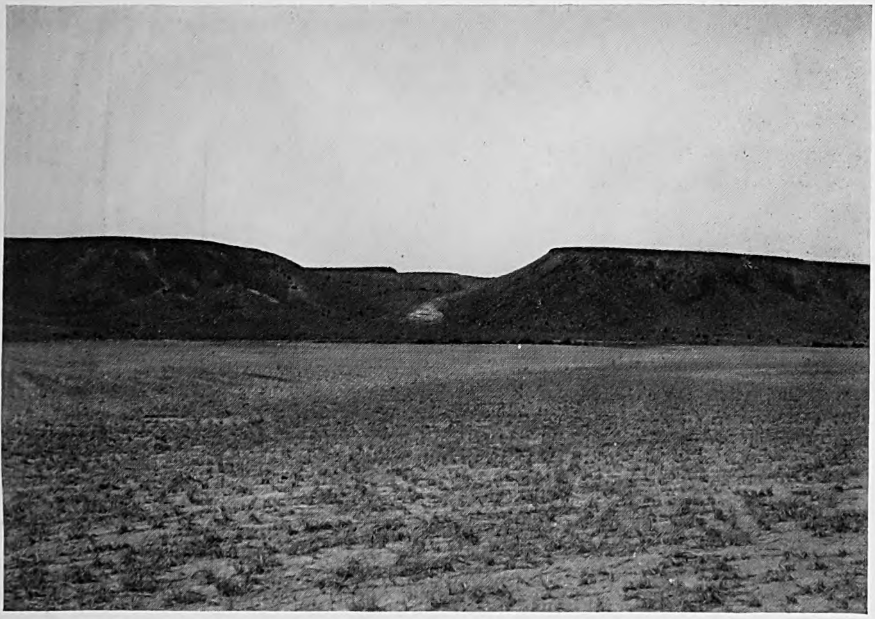

FIG. 2—Mascall formation overlain by Rattlesnake (?) rhyolite, 15 miles above Post
Photograph by Chester Stock

Elsewhere the thickness of this formation reaches 60 feet. In the absence of fossil evidence, its final reference to the Rattlesnake formation can not now be made.

Intruding the leaf shales on the Gray Ranch is a pipe of rhyolite some 30 feet in diameter. A quarter of a mile to the east the Upper John Day beds are capped with rhyolite 50 to 75 feet thick. It lies essentially horizontally on their eroded edges, having much the same structural relation as the Rattlesnake formation at Picture Gorge in the John Day Basin, which overlies the Mascall formation and the Columbia Lava with a structural unconformity. The Gray Ranch rhyolite is lithologically like that to the eastward, where it overlies the Mascall formation and may be tentatively considered to be of the same age. Similar rhyolite occurs on the south side of the Crooked River near the Ream Ranch and farther south at Logan Butte, in both places lying upon the folded edges of the John Day beds. The possibility has previously been mentioned that this rhyolite is a part of the John Day Series, but its lithologic resemblance to the Rattlesnake and its divergent structure favor its tentative reference to the Rattlesnake formation, of Pliocene age.

## COMPARISON WITH SECTION IN JOHN DAY BASIN

The sequence of the Tertiary formations in the Crooked River Basin is identical with that in the John Day Basin. The Clarno formation is made up of essentially the same types of igneous rocks and tuffs and contains a flora similar to that at Cherry Creek and Clarnos Ferry in the John Day Basin. The John Day Series of both basins rests unconformably upon the Clarno. In the Crooked River Basin proper it differs in the greater development of the Lower Division, with a correspondingly less representation of the Middle and Upper Divisions. Not far to the south, at Logan Butte, which lies in the Crooked River drainage, the total thickness of the Series reaches 3,000 to 4,000 feet, which is as great or greater than any known thickness in the John Day Basin. The flora of the Bridge Creek shales, or Lower Division, is practically identical with that on Bridge Creek and elsewhere in the John Day Basin, and the vertebrate fauna on the Middle and Upper Divisions, so far as known, also corresponds closely.

The Columbia Lava of the two basins is of the same thickness and is made up of the same number of flows. The Mascall and Rattlesnake (?) formations have received comparatively little study in the Crooked River Basin, but what is known of the fauna of the former relates it definitely to the Mascall of the John Day Basin, and in the case of both formations there is a close lithologic resemblance to their John Day Basin equivalents.

# THE CLARNO FLORA

## GEOGRAPHIC AND STRATIGRAPHIC OCCURRENCE

The sedimentary portions of the Clarno formation are largely composed of coarse tuffs and agglomerates, as a result of which only a limited number of fossil localities have been discovered in it, either in the John Day or the Crooked River Basins. The single plant locality known in the Crooked River Basin is situated on the Riverside Ranch, 34 miles up the River from Prineville. Somewhat less than half a mile north of the Highway, on the west bank of Wickieup Creek, is a conspicuous knob of Clarno tuff showing the following section:

**8 to 12 feet—Basaltic agglomerate in a coarse grayish-brown tuffaceous matrix.**
**7 feet —Coarsely bedded grayish-brown tuff with some basalt fragments.**
**3 inches —Comparatively fine-grained ashy tuff containing leaf impressions. Locality 3745.**
**10 feet —Coarse grayish-brown tuff with some basalt fragments.**

**25 to 29 feet**

These beds are situated near the base of the Clarno section as exposed in the Crooked River Basin. (See plate 2, fig. 2.)

## COMPOSITION OF THE FLORA

Due to the extremely hard character of the tuffaceous matrix, it is difficult to secure complete specimens, and only small collections have been made. Enough material has been secured, however, to indicate that it is closely related to the flora of the Clarno formation from Cherry Creek and Clarnos Ferry in the John Day Basin. The following species are tentatively listed, using the names applied by Knowlton[1] in all cases where species noted by him have been recognized.

Pinus (?) sp. What appears to be a pine of the 5-needled type is of rather common occurrence.
Quercus furcinervis americana Kn.
Sassafras sp. Several large leaves of a species apparently new.
Platanus cf. nobilis Newb. Large leaves may be referable to this species. The specimen figured as Phyllites sp. by Knowlton[2] appears to be of this type.
Rhamnus cleburni Lesq.

## PHYSICAL INDICATIONS OF THE FLORA

In the case of a flora of this size and degree of preservation, little can be stated as to its physical significance. All of the Clarno species belong to genera which are typically temperate at the present time. They may be supposed to have occupied a more open type of country than the Bridge Creek assemblage which lived in this region at a somewhat later time.

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[1] **Knowlton, U. S. Geol. Surv., Bull. 204, 21, 1902.**
[2] **Op. cit., p. 85, pl. xvii.**

## CORRELATION

The resemblance of the Clarno flora from the Crooked River to that at Cherry Creek in the John Day Basin has already been mentioned. Recent collections by the writer in the vicinity of Clarnos Ferry also bear out this relationship. Three of the five species, *Quercus furcinervus americana*, *Platanus* cf. *nobilis* and *Rhamnus cleburni*, have been noted at these John Day Basin localities. In view of a corresponding similarity in lithology and stratigraphic occurrence, the age of the floras from the two basins may be assumed to be essentially the same.

Knowlton has referred the Clarno (Lower) flora of the John Day Basin to the Lower Eocene, on the basis of the occurrence of a considerable number of species in the Fort Union. The writer is not prepared to question seriously this reference, but wishes to point out at this time several reasons for supposing that this flora may be as young as Lower Oligocene:

(1) Most of the known Eocene floras from Washington and Oregon contain either a conspicuous palm or Sequoia element; a flora of probable Eocene age from near Pilot Rock, Oregon, 125 miles to the northeast, is made up largely of the remains of palm leaves. Neither palms nor Sequoia have been noted in the Clarno flora.

(2) Several of the supposedly typical Fort Union species have been recently recorded from younger horizons, including *Lygodium kaulfusii* from the Oligocene of Manchuria and *Quercus furcinervis americana* from the Lower Oligocene at Goshen, Oregon.

(3) The flora described by Knowlton[1] from Fossil, Oregon, and referred to the Bridge Creek horizon, appears to occur not in the John Day Series but in the Clarno formation, probably in its upper portion. This flora is so like the typical Bridge Creek flora of Upper Oligocene age, from elsewhere in the John Day Basin and from the Crooked River Basin, as to indicate no great lapse in time between them. It therefore seems unlikely that the Clarno formation can be as old as Lower Eocene unless its lower portion is much older than its upper portion.

In summary it may be stated that while the age of the Clarno flora can not be definitely shown to be younger than Lower Eocene, there are several indications that it may be as recent as Lower Oligocene. With the completion of the study of the Clarno flora from the John Day Basin, new light may be thrown upon the problem of its age.

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[1] *Op. cit.*, 105.

# BRIDGE CREEK FLORA

## GEOGRAPHIC DISTRIBUTION

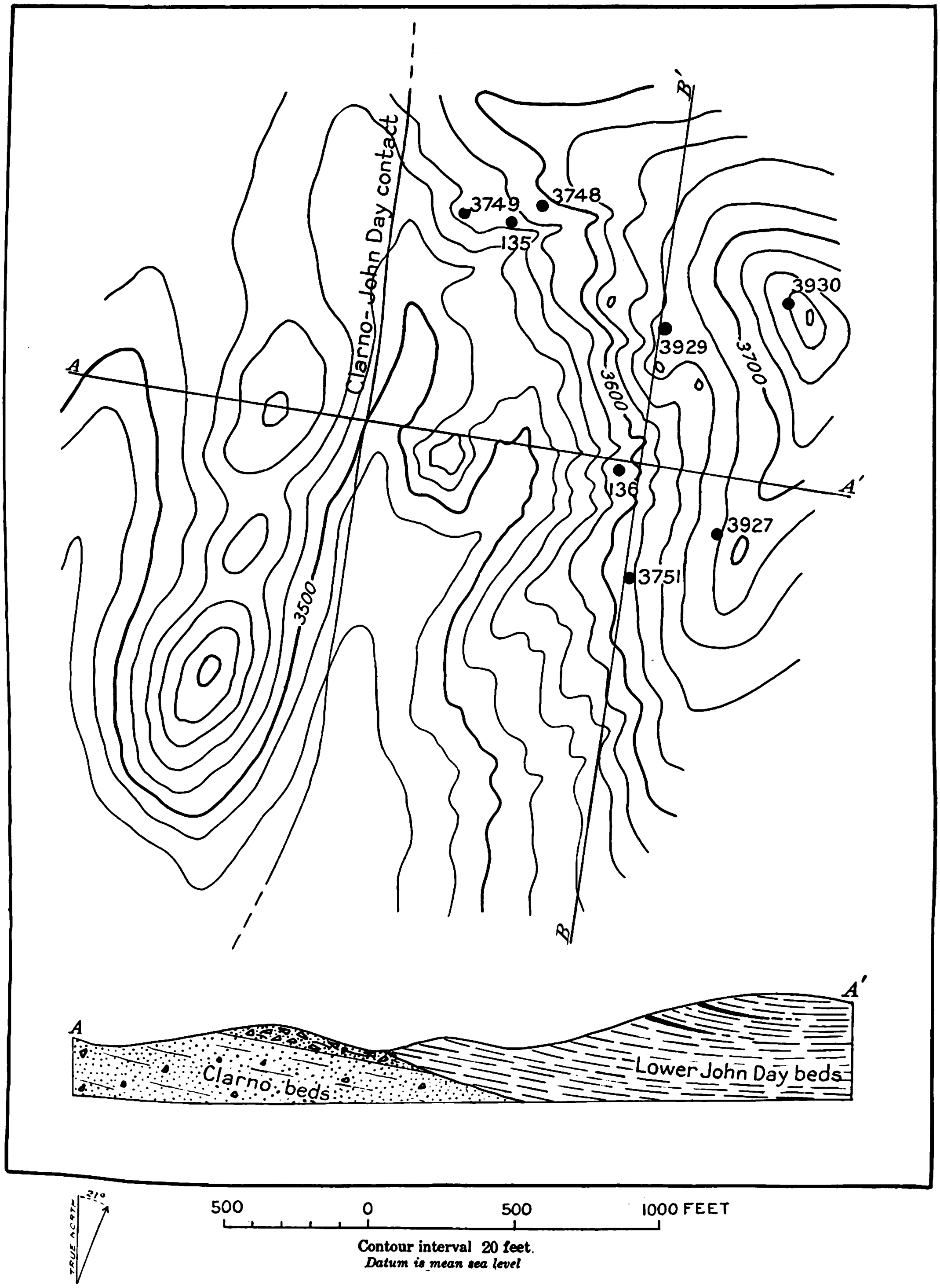
Although the John Day Series is of rather wide extent along the Crooked River, the known occurrence of plant fossils in its lower portion is restricted to a rather limited area on and near the ranch of Otto C. Gray, 11 miles east of Post and about 50 miles by the River Highway to the southeast of Prineville. It is probable that other localities will be discovered when the geology of the Crooked River Basin is studied in greater detail.

Somewhat more than a mile to the east of the Gray ranch-house, on the north side of the Crooked River, a mud-covered, rounded hill of red and light-colored banded tuffaceous shale makes up a conspicuous feature at the head of a dry wash. On the slopes of the ridge to the north and east of this hill occur most of the fossil plant localities, comprising Nos. 135, 136, 3748, 3749, 3751, 3927, 3929 and 3930; they are all in the western part of section 36, Range 20 East, Township 16 South. Locality 3750 lies a mile and a half to the northwest, in the center of Section 26, Range 20 East, Township 16 South. Locality 137 is on the south side of the Crooked River, 2.5 miles southwest of the group of localities on the Gray Ranch; it is situated near the Ream ranch, on land of the Oregon and Western Colonization Company.

## STRATIGRAPHIC OCCURRENCE

The relation of the leaf shales in the Lower division of the John Day Series to the underlying Clarno formation is most clearly apparent on the Gray Ranch. For that reason the detailed discussion of the stratigraphic relations will be confined to this area, and the occurrence of the fossil-bearing deposit on the south side of the river will be considered in the detailed discussion of that locality.

Although the details of the contact between the John Day Series and the Clarno formation on the Gray Ranch have been obscured by erosion, the relations of the two formations are clearly indicated by the topography. A few hundred feet to the west of the banded hill and the associated fossil localities, a ridge of Clarno 100 to 120 feet high trends northward and slightly to the west. This ridge forms a distinct boundary between the two formations for a distance of a mile or more northward, which is as far as the beds have been traced. To the west, hills of Clarno tuff rise several hundred feet above the ridge, and the formation is continuous for a distance of about 25 miles down the valley of the Crooked River. The accompanying topographic map, which also indicates the position of the Clarno-John Day contact, was made by the writer to bring out these stratigraphic relations. Details of the topography are somewhat generalized, but the map gives an accurate representation of relations of the Clarno ridge to the John Day Series on the east, and shows the exact position and elevation of



Map of the Gray Ranch Area showing the fossil localities and a section indicating the relations of the Clarno formation and the John Day Series

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each of the eight fossil localities occurring here; it also suggests the more broken type of topography developed in the John Day beds.

Some difficulty was experienced in securing accurate strike-and-dip readings on the Clarno formation due to the irregular character of the bedding. However, sufficient data are available to indicate that it and the John Day beds have an essentially uniform dip of 8° to 10° toward the east, the strike varying from almost due north-and-south to north-8°-east; in the upper part of the John Day Series the dip of the beds is as high as 15°. Taking a dip of 10° for the beds at the contact, the section A-A, which accompanies the topographic map with profile drawn to scale, shows that the John Day Series lies unconformably upon the Clarno.

The map was made by the plane-table-stadia method, using a telescopic alidade. The elevation was carried in by means of an aneroid from a United States Geological Survey benchmark at the Riverside Ranch, 15 miles distant, and is therefore only approximately correct.

It is probable that the topography at the time of the deposition of the John Day Series had a considerably higher relief than is indicated by the present-day profile. The valley to the west of the Clarno ridge, which separates it from the high Clarno hills farther to the west, is clearly of recent origin, resulting from more rapid erosion of the red tuffs at this point and the comparatively resistant character of the coarse yellowish gray tuffs which cap both the ridge and the hills. A second section, generalized to include the major topographic features at the Gray Ranch locality, brings out the probable character of the Clarno surface at the beginning of the John Day epoch. It is based on instrumental measurements of the existing Clarno outcrops to the west of the area mapped, and upon an assumption of the probable amount of recent erosion. In this section the Clarno formation and the John Day Series are shown in horizontal position to further approximate the conditions at the time of John Day deposition. The line C-C′ represents the actual profile of the existing surface, and the line D-D′ the hypothetical profile of the Clarno surface at the beginning of the John Day epoch.

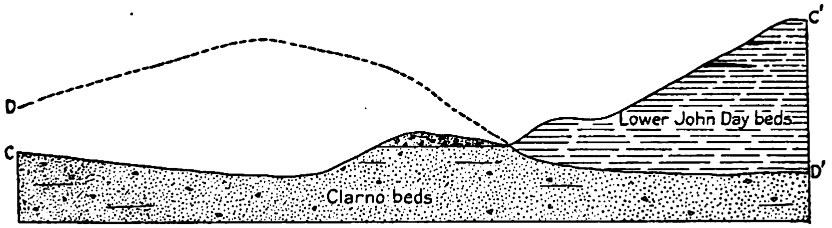

Fig. 1—Generalized section showing relations of Clarno formation and John Day Series

There is no indication at this point of any structural irregularity which would indicate that faulting has taken place. At Locality 3750, a mile and a half to the northwest, the leaf shales are on edge, suggesting that faulting may have occurred there, but in view of the limited extent of these tilted beds, their abnormal attitude may probably be better attributed to slumping. There is evidence of a Clarno surface of considerable relief at other points in the Crooked River Basin, as described in the preceding discussion of the geology of the region and in the John Day Basin as well. In addition, as will be pointed out below, the character of the Bridge Creek flora is such as to indicate a topography characterized by well-developed valleys. From the relation of the Lower John Day beds and the Clarno formation at Gray's Ranch and elsewhere it is clear that the surface on which the Lower John Day beds were deposited was cut by valleys in which the leaf-bearing Bridge Creek shales were laid down.

Interbedded with the red and buff-yellow tuffaceous shales, which make up the greater portion of the Lower division of the John Day Series and which tend to weather into rounded, mud-covered hills and slopes, are layers of dense white or gray ashy shale containing the fossil plants which, because of their superior hardness not uncommonly form the caps of the hills and ridges. These layers are at most only 2 or 3 feet in thickness and are for the most part of small lateral extent. This is consistent with their mode of origin, representing as they do the accumulation of pyroclastic material in forest-bordered depressions, as will be more extensively discussed below. An analysis of a shale specimen from Locality 3748, by Max Littlefield at the sedimentation laboratory of the State University of Iowa, indicates that it is made up of microcrystals of sanadine feldspar up to 0.03 mm. in diameter and volcanic glass of which the fragments vary in diameter from 0.005 to 0.23 mm., with 95 per cent of the grains below 0.02 mm.; the larger grains, 0.05 to 0.23 mm. in diameter, are commonly stringy and bubbly, with fine appendages. This material is firmly cemented by hydrous silica mixed with exceedingly fine, pumice-like material. The laminated character of the shale and the fine appendages on the larger glass fragments may both be taken as indicating its deposition in quiet water.

The accompanying diagram (plate 7, fig. 2), in which the horizontal and vertical scales are equal, indicates the distribution of the leaf-bearing shales in the section at the Gray Ranch, as viewed from the west. It is drawn along the average strike of the beds which is taken as north 8° east, in a plane designated on the map (plate 6) as B-B′ passing through Localities 3929 and 3751, which are centrally located. The other localities, which lie up-dip or down-dip from this plane, are projected upon it in such a way as to show approximately their relative vertical position, assuming an average dip of 10°.

Accompanying this diagram is a photograph of the exposure of leaf shales as viewed also from the west. The banded hill near the base of the section is in the center of the picture.

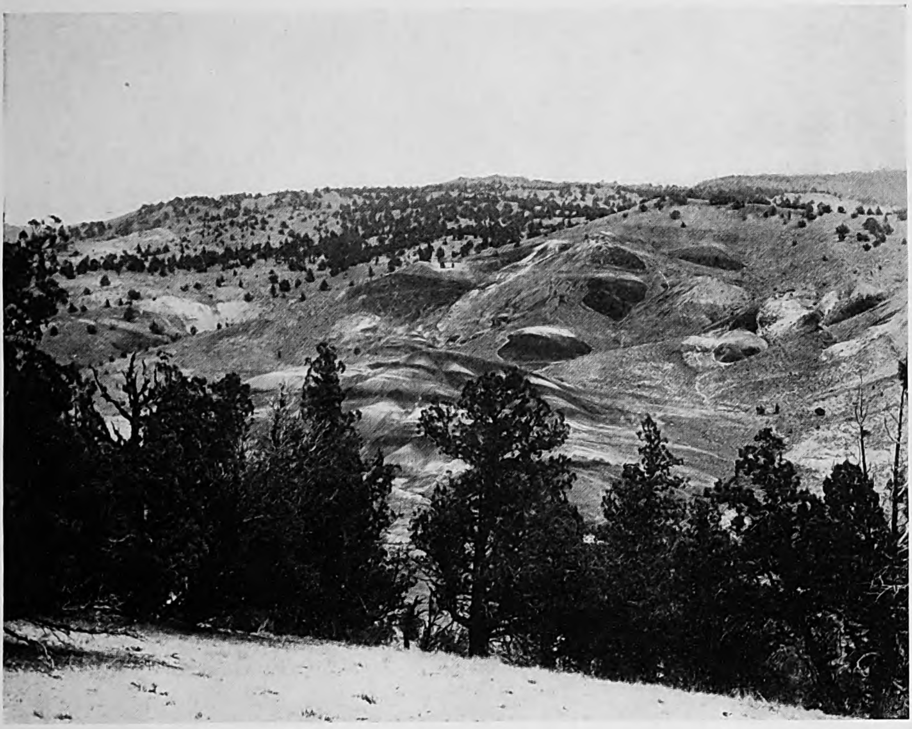

FIG. 1—Gray's Ranch fossil localities in Lower Division of John Day Series, as viewed from west. Trees on ridges are junipers, with a few pines, *P. ponderosa*, in foreground.

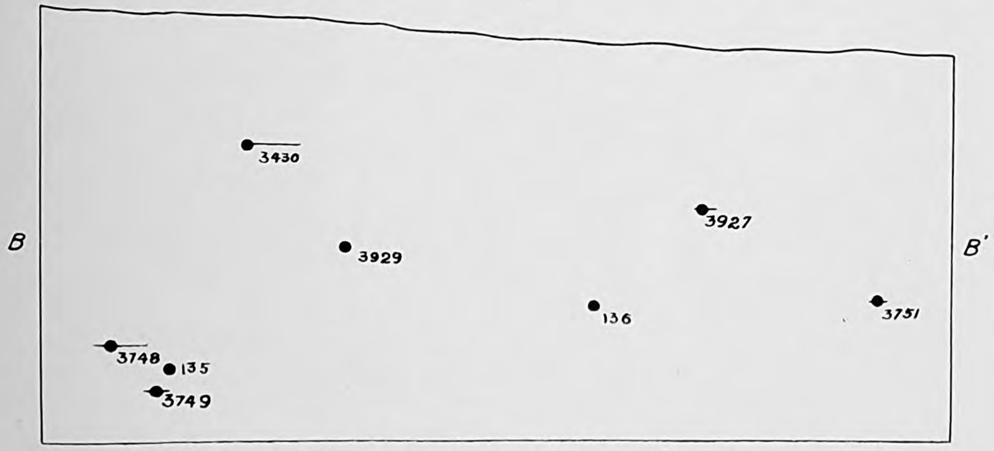

FIG. 2—Gray's Ranch fossil localities diagrammatically shown in lateral and vertical positions with relation to Plane B–B′, as indicated on Plate 6. Horizontal and vertical scales are equal.

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While the reddish and yellowish shales of the Lower Division of the John Day Series are not directly overlain by the Middle and Upper divisions at the Gray Ranch, beds having the appearance of the Upper John Day lie stratigraphically above, perhaps a quarter of a mile to the east of the plant-bearing hills. On the east limb of the structure, however, the red shales are immediately overlain by typical green beds representing the Middle division and by buff beds representing the Upper division, without any observed evidence of a break.

## ASSOCIATED VERTEBRATE AND INVERTEBRATE FOSSILS

No vertebrate fossils have been found in the Bridge Creek shales other than the remains of fish, which are of not infrequent occurrence in the leaf deposits on the Gray Ranch. In the course of the leaf count, 9 specimens were noted at Locality 3748, and 1 specimen each at Localities 3749 and 3930, giving a total of 11 specimens, or slightly more than a third of a per cent of the total of 3,201 plant specimens recorded. This material has been examined by Dr. David Starr Jordan, who states that it represents two species, neither of which is sufficiently well preserved to make a final determination possible. The more abundant of these suggests a relationship to *Columbia transmontana,* a species now living in the Columbia River Basin and reported from the mouth of the Walla Walla River. This species has only one other living representative of its family, a species known as *Erismatopteris endlicheri,* which occurs at Lake Okoboji, Iowa. It is possible that the fossil form is related to *Leuciscus turneri* Lucas, from the Esmeralda formation of Nevada, which it resembles in size and apparently in other particulars. The other fossil species is represented in the Gray Ranch collections by fragmentary remains which indicate that it was of the bony-plate type. Dr. Jordan has suggested its possible reference to the genus *Pholidophorus,* of which a fossil species, *P. americanus* Eastman, from the Jurassic of South Dakota, has the eyes surrounded by bony plates much like those of the Gray Ranch specimens.

While no effort has been made to establish the exact taxonomic position of this material, it is of interest to note that both forms are fresh-water fishes, and that the more abundant of them appears to be closely related to a species now living in the Columbia River Basin.

Leaf galls are rather common on leaves of *Acer osmonti* and *Alnus carpinoides.* In addition two other types of insect remains have been collected at the Gray Ranch. All of this material has been submitted to Professor T. D. A. Cockerell, who has written the following statement and prepared the accompanying illustrations (pages 64 and 65).

## TERTIARY FOSSIL INSECTS FROM EASTERN OREGON

By T. D. A. Cockerell

I am indebted to Dr. R. W. Chaney for the opportunity to describe the first fossil insects found in Oregon.

### ODONATA

#### Somatochlora oregonica, new species

Represented by portions of two wings from nodus to near apex, including pterostigma. Wing clear hyaline, nervures and stigma brown; nodus to stigma 12 mm., with 7 cross-veins and consequently 8 cells, the longest being the seventh (2 mm.), but equaled by the lower face of first and upper face of last; stigma 3.7 mm. long, its ends very oblique; no brace vein, but the first cross-vein below the stigma is oblique, the other (there are only two) vertical; first two cross-veins beyond stigma very oblique, contrasting with the transverse veins of the series immediately below (as in *S. provocans* Calvert); first cell beyond subnodus very long (5 mm.), equal to 3 cells above it (in most species it is equal to more than 3); 6 cells between subnodus and base of stigma, the sixth going half a millimeter below stigma; from near middle of lower side of second cell below stigma is a vein proceeding obliquely downward and apically, forming an acute angle with first media and enclosing several cells (this is equally distinct in the hind wing of *S. archica* Zett.); cells between first and second media (which separate at lower end of subnodus) 7 single (the first long), then many double; cells between second media and radial sector are double, at least as far basally as below stigma (as may be seen in *S. arctica*)

*Occurrence*—11 miles east of Post, Oregon; locality 3748, in the Lower Division of the John Day Series.

This appears to be a typical *Somatochlora*, differing no more from recent species than they do from another. The genus is essentially Holarctic, and in the opinion of Dr. E. M. Walker, who recently (1925) published an admirable monograph on the North American species, "it is doubtful whether any of the species reported from New Zealand and the East Indian Islands should be retained in the genus, and the South American *S. villosa* is a *Paracordulia*."

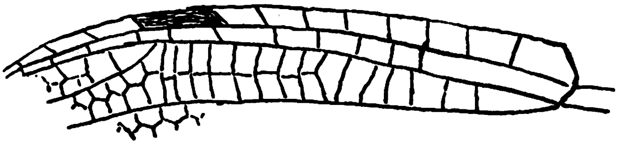

Fig. 2—Somatochlora oregonica

### DIPTERA

#### Cecidomyia chaneyi, new species

Galls on leaves of *Acer osmonti;* about 3 mm. in diameter, appearing as more or less dark circles with light center, placed usually in the vicinity of the veins.

These agree in appearance with the modern (North American) galls of *Cecidomyia ocellaris* Osten-Sacken on soft maple. Although *C. ocellaris* galls were described and named in 1862 and are common, Felt (1925) states that "repeated efforts to obtain adults have been unsuccessful." I fear they are not likely to be any more successful in the case of the fossil.

*Occurrence*—11 miles east of Post, Oregon: Locality 3930 on leaf of *Acer osmonti* (the specimen figured), in the Lower Division of the John Day Series.

Similar objects from the same region at Locality 3748 occur on leaves of *Alnus carpinoides;* these doubtless represent a distinct species, not capable of definition on the material available. Galls of this general appearance on leaves of modern *Alnus* are not due to *Cecidomyia*, but to mites (*Eriophyes laevis* Nalepa).

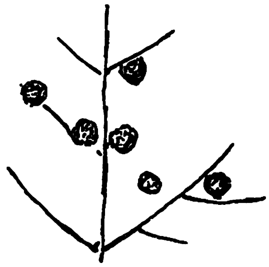

FIG. 3—Cecidomyia chaneyi

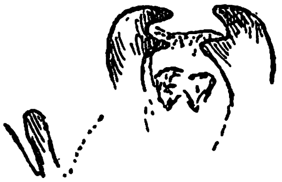

FIG. 4—Passalus (?) indormitus

## COLEOPTERA

### Passalus (?) indormitus, new species (Passalidae)

Probable length 30 mm., but only 25 mm. preserved, the apical region of the elytra having been broken off on another piece of rock. Head and thorax together about 12 mm. long; width across elytra 9 mm.; mandibles massive, strongly curved, with two large inwardly directed teeth; base of antenna to club about 3.7 mm.; two first joints of club visible, the projecting portion about 1 mm. long, parallel-sided, obtuse; elytral striae about four (three intervals) in 2 mm., the punctures so faint and small as to be very obscure, but they are seen in ventral view.

*Occurrence*—11 miles east of Post, Oregon; Locality 3748, in the Lower Division of the John Day Series.

The specimen is poorly preserved, but fortunately there is enough of one antenna to show, with the other characters, that it belongs to Passalidae. The family is very conservative as to the general appearance of its members, and must be of great antiquity. Thus, on casual examination, *Dineleus*[1] *interstitialis* Esch. from Quirigua, Guatemala (W. P. Cockerell), looks exactly like the Australian *Aulacocyclus edentulus* Macl. They also very closely resemble the fossil. In the present Nearctic fauna the Passalidae are very poorly represented, with only *Passalus cornutus* Fabr. (Eastern United States from Connecticut to Florida and Texas), and *Dineleus tlascala* Perch. from Lower California and Mexico.

The fossil is pale, and was probably red in life, like *Rhodocanthopus punctatostriatus* Perch., from Quirigua, Guatemala.

## PLANT-BEARING OUTCROPS

The Lower John Day beds, also designated as the Bridge Creek shales, have yielded fossil plants at 10 localities. Of these 8 lie in a limited area 11 miles east of Post on the Gray Ranch, about a mile east of the ranch house, in the western part of Section 36, Range 20 East, Township 16 South. Another is situated 1.5 mile to the northwest of this area, also on the Gray Ranch, and the last lies across the Crooked River, some 2.5 miles to the southwest, near the Reams Ranch.

Although the eight localities at the principal area all lie within short distances horizontally and vertically of each other, their occurrence in layers of ashy shale which have short lateral extent makes it desirable to consider each as a distinct unit with an individual number, as indicated in plate 7, figure 2. These localities will be considered in the order of their vertical sequence from the base of the section, followed by the description of the isolated localities to the northwest and the southwest.

---

[1] *Dineleus*, new name for *Neleus* Kaup., preoccupied.

### LOCALITY 3749

About 80 feet above the base of the Lower division of the John Day Series, stratigraphically above the banded shales which make up the central hill and immediately overlying some 30 feet of loose yellowish-white tuffaceous shale, a layer of grayish-white ashy shale containing leaf impressions outcrops for a distance of about 50 feet along the west end of the ridge near the top. The shale is highly indurated, weathering out in slabs a foot or more in length and width, and a few inches thick. It splits readily along the bedding plains, and is conspicuously stained with iron. The following 13 species occur here, their percentage representation being noted below in table 2 (p. 78).

Acer osmonti
Alnus carpinoides
Celtis obliquifolia
Crataegus newberryi
Fagus pacifica
Ostrya oregoniana
Platanus aspera
Porana speirii
Pteris silvicola
Quercus clarnensis
Quercus consimilis
Ulmus brownellii
Umbellularia oregonensis

### LOCALITY 135

160 feet to the southeast of Locality 3749 and at about the same elevation, though stratigraphically 29 feet above it, a few cubic feet of brown lignitic shale were found surrounded by the typical light-colored and reddish tuffaceous shale and probably representing a mass which had slumped from an original position above. From the occurrence of a similar lignitic shale near the base of the Lower John Day on Bridge Creek in the John Day Basin, it may be inferred that this loose material is not far from its original position. It is more finely bedded than the typical leaf shales at the Gray Ranch, some of it being almost a paper shale. Plant remains, representing for the most part the leaves of cat-tails, are more abundant here than at any of the other localities in the Crooked River Basin, with the following species noted:

Alnus carpinoides
Castanea orientalis
Corylus macquarrii
Cyperacites sp.
Fraxinus denticulata
Grewia crenata
Juglans oregoniana
Myrica diforme
Ostrya oregoniana
Pinus knowltoni
Platanus aspera
Pteris silvicola
Quercus clarnensis
Quercus consimilis
Salix californica
Sequoia langsdorfii
Typha lesquereuxi

### LOCALITY 3748

This is the principal locality at the Gray Ranch, the leaves occurring in a dense, fine-grained, grayish-white ash, in layers 8 to 10 inches thick, which ordinarily split readily along the bedding planes. It lies 270 feet east along the ridge from No. 3749, and stratigraphically 72 feet above it. The ash is highly jointed, coming out in blocks 12 to 15 inches square, and weathering pure white; on the slopes below this and most of the other localities lie numerous white fragments which contain fragmentary leaf impressions. Most of the pieces of silicified wood occur on the slopes below this locality and No. 3749.

The lateral extent of the fossiliferous ash layer is greater here than at any other locality, running some 125 feet along the side of the ridge, 15 to 20 feet below its crest. The abundance of fossil specimens varies considerably within the deposit; they occur in greatest numbers at about the center of the excavation and are much less numerous on either side and to the north into the hill. A total of about 45 cubic feet of shale was dug out and split, representing an area 6 feet long and 5 feet wide, the average thickness of the fossiliferous layer being 1.5 feet. The section is as follows:

| | |
|---|---|
| 15 inches (to top)... | Gray, finely bedded ashy shale, containing leaves. This is highly fractured, representing a weathered phase of the layer below. |
| 15 to 20 inches..... | Dense gray ashy shale, in beds 8 to 10 inches thick with yellow clay at the partings; contains abundant leaf impressions. |
| 40 feet............ | Red and yellowish buff tuffaceous shale, weathering to loose sand. |

A total of 38 species has been secured here, as shown in the following list:

Abies sp.
Acer osmonti
Alnus carpinoides
Amelanchier grayi
Arbutus matthesii
Asarum circularis
Carpinus grandis
Castanea orientalis
Celtis obliquifolia
Cercis sp.
Ceanothus blakei
Cornus ovalis
Crataegus newberryi
Fagus pacifica
Fraxinus denticulata
Grewia crenata
Juglans oregoniana
Nyssa crenata
Odostemon simplex
Ostrya oregoniana
Philadelphus bendirei
Pinus knowltoni
Platanus aspera
Platanus condoni
Prunus coveus
Quercus clarnensis
Quercus consimilis
Rosa hilliae
Rhus merrilli
Rhus praeovata
Salix californica
Sequoia langsdorfii
Taxus sp.
Tilia sp.
Typha lesquereuxi
Ulmus brownellii
Ulmus speciosa
Umbellularia oregonensis

### LOCALITY 136

59 feet stratigraphically above No. 3748 and lying 950 feet to the southeast, leaf-bearing shale has a limited outcrop in a small gully. The shale is lithologically similar to that at No. 3748; it has an observed thickness of not more than 1.5 feet, passing into light-colored tuffaceous shale above, and being underlain by 15 feet of yellowish-buff tuffaceous shale. The following species have been recorded here:

Alnus carpinoides
Ostrya oregoniana
Platanus aspera
Quercus clarnensis
Typha lesquereuxi
Ulmus brownellii
Ulmus speciosa

### LOCALITY 3751

A foot or two of ashy shale is exposed at the top of a short spur, 13 feet stratigraphically above No. 136 and 375 feet to the south along the ridge. Leaf impressions occur in a matrix similar to that of the two preceding localities, and it is possible that this represents an extension of the shale of No. 136 on an irregular surface. Due to weathering, the fossil material is poorly preserved, comprising the following species:

Acer osmonti
Alnus carpinoides
Cyperacites sp.
Grewia crenata
Pinus knowltoni
Ostrya oregoniana
Platanus aspera
Prunus coveus
Quercus clarnensis
Sequoia langsdorfii
Typha lesquereuxi

### LOCALITY 3929

A foot or more of leaf-bearing ashy shale outcrops at the top of a high red hill 89 feet stratigraphically above No. 3751 and 850 feet to the north. It is lithologically similar to that of the localities below, and in like manner weathers out in thin slabs and flakes which become greatly hardened on exposure to the atmosphere. The tuffaceous shale below is yellowish buff in color. Due to the weathered condition of this deposit, the number of species noted is limited:

Alnus carpinoides
Ceanothus blakei
Celtis obliquifolia
Fagus pacifica
Odostemon simplex
Ostrya oregoniana
Platanus aspera
Prunus coveus
Quercus clarnensis
Rosa hilliae
Sequoia langsdorfii
Ulmus brownellii
Umbellularia oregonensis

### LOCALITY 3927

A layer of fossiliferous shale a foot in thickness has a lateral extent of some 40 feet about 750 feet to the southeast along the ridge and at a level 58 feet stratigraphically above No. 3929. It is rather carbonaceous, in this respect resembling the matrix at No. 135 more closely than any other; it differs from this in being less finely bedded. The yellow tuffaceous shale below grades into red shale at the north. The leaf impressions are rather poorly preserved, including the following species:

Acer osmonti
Alnus carpinoides
Carpinus grandis
Ceanothus blakei
Ostrya oregoniana
Pinus knowltoni
Platanus aspera
Quercus clarnensis
Sequoia langsdorfii
Ulmus brownellii
Umbellularia oregonensis

### LOCALITY 3930

93 feet stratigraphically above No. 3927, a layer of leaf-bearing shale a foot in thickness extends for about 100 feet along the ridge and 15 feet below its crest. This shale is thinly bedded and darker in color than the typical shales of the Gray Ranch, its reddish-gray weathered surfaces more closely resembling the leaf shales of the John Day Basin.

The tuffaceous shale lying below and above is yellowish buff in color and loosely weathered at the surface. The following species have been noted:

Acer osmonti
Alnus carpinoides
Carpinus grandis
Ceanothus blakei
Cercis sp.
Crataegus newberryi
Fraxinus denticulata
Ostrya oregoniana
Pinus knowltoni
Platanus aspera
Quercus clarnensis
Quercus cf. ramaleyi
Rhus merrilli
Salix californica
Sequoia langsdorfii
Typha lesquereuxi
Ulmus brownellii

### LOCALITY 3750

A mile and a half to the northwest of the principal fossil area on the Gray Ranch, in the center of Section 26, Range 20 East, Township 16 South, leaf impressions occur in a layer of ashy shale up to 2 feet in thickness. This is similar in color and texture to that at No. 3748 and other typical localities. It outcrops in a gully on the side of a hill above red tuffaceous shales, the beds standing on edge but tending toward a normal easterly dip in the lower part of the gully 150 feet down the slope. The abnormal attitude at this point is probably due to slumping, although it is possible that a small fault is involved. About half a mile to the north leaf impressions occur in loose slabs; these have been included with those from the locality proper in the following list:

Acer osmonti
Alnus carpinoides
Carpinus grandis
Celtis obliquifolia
Cornus ovalis
Crataegus newberryi
Fraxinus denticulata
Grewia crenata
Myrica diforme
Philadelphus bendirei
Platanus aspera
Quercus clarnensis
Rosa hilliae
Sequoia langsdorfii
Taxus sp.
Typha lesquereuxi
Umbellularia oregonensis

### LOCALITY 137

About 2.5 miles southwest of the principal fossil area on the Gray Ranch, a third of a mile south of the old road along the south side of the Crooked River, about 10 miles east of Post near the Ream Ranch, the Lower John Day beds with a total thickness of 300 feet dip almost due southeast at an angle of 23°. 40 to 50 feet of red tuffaceous shale, weathering to form rounded mud-covered hills and slopes, are overlain by yellowish-buff tuffaceous shale containing layers of white ashy shale closely similar to that at No. 3749. Above is a rhyolite flow similar to that described on the Gray Ranch. One-eighth mile to the north a hill of Clarno suggests that the John Day Series may rest upon an irregular surface like that elsewhere noted. The ashy shale splits readily and contains numerous leaf impressions along the bedding planes. Further collections may augment the list of species as here noted:

| | |
|---|---|
| Alnus carpinoides | Pteris silvicola |
| Celtis obliquifolia | Quercus clarnensis |
| Ostrya oregoniana | Typha lesquereuxi |
| Pinus knowltoni | Ulmus brownellii |
| Platanus aspera | |

## LOCALITIES MENTIONED OUTSIDE OF THE CROOKED RIVER BASIN

In view of the use of material collected at several localities in the John Day Basin and elsewhere to supplement the Bridge Creek speci-

TABLE 1.—*Local distribution of the Bridge Creek Flora*

| | Localities | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3749 | 135 | 3748 | 136 | 3751 | 3929 | 3927 | 3930 | 3750 | 137 |
| Abies sp | | | X | | | | | | | |
| Acer osmonti | X | | X | | X | | X | X | X | |
| Alnus carpinoides | X | X | X | X | X | X | X | X | X | X |
| Amelanchier grayi | | | X | | | | | | | |
| Arbutus matthesii | | | X | | | | | | | |
| Asarum circularis | | | X | | | | | | | |
| Carpinus grandis | | | X | | | | X | X | X | |
| Castanea orientalis | | X | X | | | | | | | |
| Ceanothus blakei | | | X | | | X | X | X | | |
| Celtis obliquifolia | X | | X | | | X | | | X | X |
| Cercis sp | | | X | | | | | X | | |
| Cornus ovalis | | | X | | | | | | X | |
| Corylus macquarrii | | X | | | | | | | | |
| Crataegus newberryi | X | | X | | | | | X | X | |
| Cyperacites sp | | X | | | X | | | | | |
| Fagus pacifica | X | | X | | | X | | | | |
| Fraxinus denticulata | | X | X | | | | | X | X | |
| Grewia crenata | | X | X | | X | | | | X | |
| Juglans oregoniana | | X | X | | | | | | | |
| Myrica diforme | | X | | | | | | | X | |
| Nyssa crenata | | | X | | | | | | | |
| Odostemon simplex | | | X | | | X | | | | |
| Ostrya oregoniana | X | X | X | X | X | X | X | X | | X |
| Philadelphus bendirei | | | X | | | | | | X | |
| Pinus knowltoni | | X | X | | X | | X | X | | X |
| Platanus aspera | X | X | X | X | X | X | X | X | X | X |
| Platanus condoni | | | X | | | | | | | |
| Porana speirii | X | | | | | | | | | |
| Prunus coveus | | | X | | X | X | | | | |
| Pteris silvicola | X | X | | | | | | | | X |
| Quercus clarnensis | X | X | X | X | X | X | X | X | X | X |
| Quercus consimilis | X | X | X | | | | | | | |
| Quercus cf. ramaleyi | | | | | | | | X | | |
| Rhus merrilli | | | X | | | | | X | | |
| Rhus praeovata | | | X | | | | | | | |
| Rosa hilliae | | | X | | | X | | | X | |
| Salix californica | | X | X | | | | | X | | |
| Sequoia langsdorfii | | X | X | | X | X | X | X | X | |
| Taxus sp | | | X | | | | | | X | |
| Tilia sp | | | X | | | | | | | |
| Typha lesquereuxi | | X | X | X | X | | | X | X | X |
| Ulmus brownellii | X | | X | X | | X | X | X | | X |
| Ulmus speciosa | | | X | X | | | | | | |
| Umbellularia oregonensis | X | | X | | | X | X | | X | |

mens of the Crooked River Basin, both in the descriptions of new species and in the illustrations, it seems desirable to list the localities so mentioned. They are as follows:

Locality 3741—The type locality of the Bridge Creek flora in the John Day Basin; 9 miles northwest of Mitchell, Oregon, commonly referred to as the Allen Ranch locality.

Locality 3739—Dug-out Gulch, 2 miles northeast of Clarnos Ferry, John Day Basin, Oregon.

Locality 132—2.5 miles northeast of Clarnos Ferry, Oregon.

Locality 3931—Cant's Ranch, Butler Basin, about 10 miles down the John Day River from Dayville, Oregon.

Localities 125, 127—Cove Creek, 5.5 miles northeast of Clarnos Ferry, Oregon.

Locality 92—Buchanan Tunnel, Table Mountain, 1.5 miles east of Columbia, California.

The type locality of the Bridge Creek flora, in the John Day Basin 9 miles northwest of Mitchell, is of great importance in the comparison of the floras of the two basins, for its florule has been more extensively collected and studied than any other in eastern Oregon. At the time of Merriam's first visit, and in his *Contribution to the Geology of the John Day Basin*,[1] it was known as the Allen Ranch locality. Although the ranch has changed hands several times since 1900, and is now the property of Mr. Ben Taylor, it has seemed desirable to continue the use of this original name.

## COMPOSITION OF THE FLORA

### QUALITATIVE CONSIDERATIONS

The Bridge Creek flora of the Crooked River Basin comprises 44 species, representing 39 genera and 28 families. Except for a single species of fern, 4 species of conifers and 2 monocotyledons, the flora is made up of dicotyledonous species. All but 4 or 5 of these appear to have been woody plants, for the most part of arborescent types.

The material occurs mostly in the form of leaf impressions, only 3 species being unrepresented by foliage. One of these, *Porana speirii* Lesq., is a species based upon the flower only and the leaves are unknown. The other 2, *Cercis* sp. and *Tilia* sp., have not been specifically named; the pods of the former may be referable, as elsewhere suggested, to the leaves which have been called *Grewia crenata* (Unger) Heer; pedunculate bracts like the one here referred to *Tilia* sp. are associated with numerous well-preserved leaves of this genus in the Bridge Creek flora of the John Day Basin.

With the exception of Lesquereux, palaeobotanists have been in the habit of giving distinct specific names to fruiting specimens, even when they are associated in the same deposits with leaves of corresponding genera. This practice may be desirable in cases where there are several leaf species of a genus in a flora, to any one of which the fruit is equally referable; or in cases where the fruit specimens are poorly preserved. But it has the disadvantage of multiplying the number of fossil species, and should be avoided where the evidence for the association of leaf and fruit material in a single species is indicated by corresponding relationships in modern material. Where only one leaf species of a genus is present in a flora which has been extensively collected, there should be no question as to the reference of fruit specimens to it. Thus the *Carpinus* fruits of the Bridge Creek flora may be confidently placed in the leaf species, *Carpinus grandis*, which is the only representative of its genus. Even where there are several leaf species of a genus in the same flora, it may be possible to accurately refer the associated fruits to one or the other of them. The common Bridge Creek leaf species of elms, *Ulmus speciosa* and *U. brownellii*, represent the fossil equivalents of two living species, *U. montana* and *U. parvifolia*, in which the leaves are readily distinguishable. There are two distinct types of fossil elm samaras which resemble the fruits of these two living species and which may therefore be confidently referred to the corresponding fossil leaf species. And if the argument be raised that the placing of fossil leaf and fruit specimens in one species is justified only in cases where they are attached, it may be replied that the same qualification should in consistency be imposed upon the placing of two fossil leaf specimens in the same species. There is as much basis for associating detached leaf and fruit specimens of *Ulmus speciosa* or of *U. brownellii* in view of the distinctive characters of their samaras and those of their living equivalents, as there is for the association of two detached leaves of *Ulmus speciosa* or of *U. brownellii.*

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[1] Univ. Calif. Dept. Geol. Bull., vol. II, No. 9, 287, 1901.

Altogether there are 15 leaf species with associated fruits, seeds or flowers, in addition to the three species above noted which are represented only by fruits. This fruiting material adds in an important way to our knowledge of the characters and relations of the fossil leaf species.

No silicified wood has been found in situ on the Gray Ranch, but pieces of it are common on the slopes, especially below localities 3748 and 3749. A number of these specimens have been sectioned by the United States Geological Survey through the cooperation of Dr. David White. The wood structure is for the most part well preserved, though several specimens show fracturing which probably took place after fossilization. These sections have been studied in a preliminary way by F. H. Frost, who has recognized a species of *Ulmus*. With the assistance of Professor E. Fritz of the University of California, the writer has identified specimens of *Alnus* and *Sequoia*. It is significant that all three of these genera are represented at the Gray Ranch by numerous leaves as well. In view of the abundance there of fossil oak leaves, the wood of *Quercus* may be expected to be found in the course of future studies.

The flora may be conveniently divided into five groups as follows: (1) The redwood element, including those species whose living equivalents are found in the coast redwood forest of California and Oregon; (2) the non-redwood western element, including species whose living equivalents are found today in western America outside of the redwood forest; (3) the eastern American element, including species whose living equivalents are now restricted to the area east of the Rocky Mountains; (4) the Asiatic element, including species whose living equivalents occur in northeastern and eastern Asia; and (5) a group of species whose taxonomic status is so uncertain as to give them no comparative value. The representation of these groups is shown in tabular form.

| | Number of species | Percentage of total species |
|---|---|---|
| Redwood Element......... | 21 | 48 |
| Non-redwood Western Element.................. | 7 | 16 |
| Eastern American Element. | 8 | 18 |
| Asiatic Element........... | 4 | 9 |
| Doubtful Element......... | 4 | 9 |

In cases where a fossil species equally resembles living forms of two of the areas as above classified, it is placed in the group geographically nearer to the fossil locality in eastern Oregon. Thus the fossil species, *Carpinus grandis,* seems equally to resemble living species in both eastern America and northeastern Asia, but it is placed in the eastern America element. This arbitrary method probably cuts down the representation of the Asiatic element considerably. In the case of most of the fossil species, however, their relation to a single living species is sufficiently well defined to indicate their grouping without question.

### THE REDWOOD ELEMENT

The most outstanding character of the flora is its resemblance to the redwood forest now occupying the coastal borders of California and southern Oregon. This relationship has been previously discussed in connection with the Bridge Creek flora from the John Day Basin,[1] and will be further considered below in connection with the statement of the physical significance of the flora. So dominant a place does this element hold that the Bridge Creek flora may be considered to represent a forest essentially like that now living in the Redwood Belt of

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[1] Chaney, Carnegie Inst. Wash. Pub. No. 349, No. I, 1925.

Pacific North America. The following list shows the fossil species of this group, together with their nearest living equivalents.

| *Fossil species:* | *Living species:* |
|---|---|
| Abies sp. | Abies grandis Lindl. |
| Acer osmonti Kn. | Acer glabrum Torr. |
| Amelanchier grayi Chaney | Amelanchier alnifolia Nutt. |
| Arbutus matthesii Chaney | Arbutus menziesii Pursh. |
| Asarum circularis Chaney | Asarum caudatum Lindl. |
| Ceanothus blakei Chaney | Ceanothus thyrsiflorus Esch. |
| Cornus ovalis Lesq. | Cornus nuttallii Aud. |
| Corylus macquarrii (Forbes) Heer | Corylus rostrata californica A. DC. |
| Fraxinus denticulata Heer | Fraxinus oregona Nutt. |
| Philadelphus bendirei (Kn.) Chaney | Philadelphus lewisii Pursh. |
| Pinus knowltoni Chaney | Pinus attenuata Lem. |
| Prunus coveus Chaney | Prunus emarginata Walp. |
| Pteris silvicola Hall | Pteris aquilina L. |
| Quercus clarnensis Trelease | Quercus chrysolepis Liebm. |
| Quercus consimilis Newb. | Quercus densiflora Hook. and Arn. |
| Rosa hilliae Lesq. | Rosa nutkana Presl. |
| Salix californica Lesq. | Salix lasiolepis Benth. |
| Sequoia langsdorfii (Br.) Heer | Sequoia sempervirens Endl. |
| Taxus sp. | Taxus brevifolia Nutt. |
| Typha lesquereuxi Ckll. | Typha latifolia L. |
| Umbellularia oregonensis Chaney | Umbellularia californica Nutt. |

The inclusion of *Typha* in this group may be questioned, since it is not actually a member of the redwood forest. However, its occurrence on the flats bordering this forest near Eureka, California, indicates the present possibility of the deposition of the remains of *Sequoia* and other associated species in a cat-tail swamp.

### Non-Redwood Western Element

Living in the Pacific Coast region today are a number of species which are never associated with the redwood but which have fossil equivalents in the Bridge Creek flora. At least two of these might perhaps be better placed in the redwood group, though strictly speaking their nearest living equivalents are not associated with the redwood. Thus *Alnus carpinoides* is obviously the ecologic equivalent of the modern redwood associate, *A. rubra;* but the living species most like it is *A. tenuifolia* whose range does not include the Redwood Belt. In like manner, *Odostemon simplex* is the ecological equivalent of *O. nervosus*, a common undershrub in the modern redwood forest; but its appearance is more like that of *O. fremontii*, which lives in the deserts of the southwest. It is apparent that certain species which were associated with the redwood during the Tertiary have been replaced by other species of their genera, in all cases closely related, in the modern redwood forest.

| *Fossil species:* | *Living species:* | *Nearest occurrence to Redwood Belt:* |
|---|---|---|
| Alnus carpinoides Lesq. | Alnus tenuifolia Nutt. | Sierra Nevada |
| Celtis obliquifolia Chaney | Celtis douglasii Plan. | Eastern Oregon |
| Cercis sp. | Cercis occidentalis Torr. | California Coast Ranges |
| Juglans oregoniana Lesq. | Juglans californica Wats. | Coastal South California |
| Odostemon simplex (Newb.) Ckll. | Odostemon fremontii Rydb. | Mohave Desert |
| Quercus cf. remaleyi Ckll. | Quercus sadleriana R. Br. Campst. | S. W. Oregon and N. W. California |
| Rhus praevota Chaney | Rhus ovata Wats. | Montane South California |

### Eastern America Element

All of the Miocene and older Tertiary floras of western America contain a considerable number of deciduous species belonging to genera no longer occurring west of the Rocky Mountains. It is possible that their disappearance on the Pacific Coast is due to their inability to permanently establish themselves in a region with the seasonal climate of the ocean border, involving dry summers and moist winters, or there may have been climatic changes in this region since the Oligocene, perhaps during Pleistocene glaciation, which have made it an undesirable habitat for them. The following Bridge Creek species are of this group.

| *Fossil species:* | *Living species:* |
|---|---|
| Carpinus grandis Unger | Carpinus caroliniana Walt. |
| Fagus pacifica Chaney | Fagus grandifolia Ehrh. |
| Myrica diforme (Berry) Chaney | Myrica asplenifolia L. |
| Nyssa crenata Chaney | Nyssa sylvatica Marsh |
| Ostrya oregoniana Chaney | Ostrya virginiana K. Koch. |
| Platanus aspera Newb. | Platanus occidentalis L. |
| Tilia sp. | Tilia glabra Vent. |
| Ulmus speciosa Newb. | Ulmus fulva Michx. |

It should be emphasized that practically all of these fossil species have living equivalents in Asia as well as in eastern North America; in the case of *Ulmus speciosa*, the resemblance to *U. montana* of Europe is even closer than to *U. fulva* of eastern America.

### Asiatic Element

The following list includes the fossil species which have no living equivalents in North America today, but which are closely related to modern species of Asia.

| *Fossil species:* | *Living species:* |
|---|---|
| Castanea orientalis Chaney | Castanea henryi Rehd. |
| Crataegus newberryi Ckll. | Crataegus pinnatifida Burge |
| Rhus merrillii Chaney | Rhus sylvestris S. & Z. |
| Ulmus brownellii Lesq. | Ulmus parvifolia Jacq. |

The list is considerably augmented by adding the fossil species which have living equivalents both in Asia and America.

| *Fossil species:* | *Modern Asiatic species:* |
|---|---|
| Abies sp. | Abies sibirica Ledeb. |
| Alnus carpinoides Lesq. | Alnus alnobetula Ehr. |
| Carpinus grandis Unger | Carpinus laxiflora Bl. |
| Cercis sp. | Cercis chinensis Bunge |
| Cornus ovalis Lesq. | Cornus kousa Buerg. |
| Corylus macquarrii Heer | Corylus heterophylla Fisch. |
| Fagus pacifica Chaney | Fagus longipetiolata See. |
| Nyssa crenata Chaney | Nyssa sinensis Oliv. |
| Ostrya oregoniana Chaney | Ostrya japonica Sarg. |
| Philadelphus bendirei (Kn.) Chaney | Philadelphus incanus Koch. |
| Platanus aspera Newb. | Platanus orientalis L. |
| Quercus clarnensis Trelease | Quercus baroni Skan. |
| Quercus consimilis Newb. | Quercus delavayi Franch. |
| Rosa hilliae Lesq. | Rosa—several species |
| Salix californica Lesq. | Salix phylicifolia L. |
| Taxus sp. | Taxus chinensis Rehd. |

In addition there are several other Asiatic species whose resemblance to fossil species is striking, although not as close as that of North American species.

| *Fossil species:* | *Modern Asiatic species:* |
|---|---|
| Acer osmonti Kn. | Acer ginnala Max. |
| Celtis obliquifolia Chaney | Celtis bungeana Hems. |
| Juglans oregoniana Lesq. | Juglans mandschurica Skan. |
| Prunus coveus Chaney | Prunus padus L. |
| Quercus cf. ramaleyi Ckll. | Quercus faleri Hance. |
| Ulmus speciosa Newb. | Ulmus macrocarpa Hance. |

Of the 40 well-defined species of the Bridge Creek flora from the Crooked River Basin, 4 have living equivalents only in Asia, 16 have equally close relatives in Asia and North America, and 6 more have somewhat less striking Asiatic affinities. A total of 26 species, or 60 per cent of the flora, has an Asiatic facies.

### THE DOUBTFUL ELEMENT

Four species are represented by material which is inadequate to a proper understanding of their relations to living species. *Cyperacites* sp. is no doubt the equivalent of one of the several species of grasses now growing on the exposed borders of the redwood forest of which *Torresia macrophylla* (Thurb.) Hitchc. is a common example. *Platanus condoni* (Newb.) Kn., as elsewhere suggested, may well represent merely a variant of the more common *Platanus aspera* Newb., which is placed in the Eastern American element. *Porana speirii* Lesq. is clearly not a true *Porana,* and the name is used here for lack of a better and without any suggestion of its modern affinities. *Grewia crenata* (Unger) Heer is probably referable either to *Cercis,* in which case it should be placed in the Non-redwood Western Element, or to *Cercidiphyllum,* in which case it would belong with the Asiatic Element.

### BRIDGE CREEK GENERA STILL LIVING IN CROOKED RIVER BASIN

A considerable number of the genera represented in the Bridge Creek flora have species now living in the Crooked River Basin or on its borders. Along the river within a mile of the fossil localities the modern flora includes species of *Alnus*, *Celtis*, *Cornus*, *Pinus*, *Rosa*, *Salix* and *Typha;* in the Blue Mountains a few miles to the north occur species of *Abies*, *Acer*, *Alnus*, *Amelanchier*, *Asarum*, *Ceanothus*, *Cornus*, *Corylus*, *Crataegus*, *Odostemon*, *Philadelphus*, *Pinus*, *Prunus*, *Pteris*, *Rhus*, *Rosa*, *Salix* and *Taxus*. Of the 39 genera making up the fossil flora, 20 have representatives in the region at the present time. Two more, *Quercus* and *Fraxinus*, are included in the forest bordering the Columbia River 100 miles to the north.

In summary it may be stated that while the Bridge Creek flora of the Crooked River Basin contains a conspicuous element of species whose living relatives occur in the Redwood Belt of California and Oregon, there are also species whose modern equivalents are found today in other parts of western America, in eastern America and in Asia; 20 of the 39 genera of the fossil flora have representatives surviving in the living flora of the Crooked River Basin and the near-by Blue Mountains.

## QUANTITATIVE CONSIDERATIONS

A total of 2,886 specimens was counted at 8 localities in the field during the 1926 season by H. L. Mason and the writer, using the method previously described in *Quantitative Studies of the Bridge Creek Flora.*[1] In addition, counts totaling 315 specimens were made in the laboratory of the collections from the two remaining localities, Numbers 3750 and 3751. While this procedure is perhaps not ideal, it has involved no appreciable error due to selective collecting, since the number of specimens originally available at these localities was small and practically all of them were collected; laboratory counts were necessary in the two cases because no more leaf-bearing shale was available at the localities. Altogether the count includes a total of 3,201 specimens from the 10 localities in the Crooked River Basin—a number wholly sufficient to establish the percentages of the dominant species in the flora, although it may not give an entirely accurate indication of the rarer species. Had a count been made at the principal locality, No. 3748, during one of the earlier years of collecting, the total number of specimens recorded would have been greater; but as is the case with most other Tertiary leaf deposits in eastern Oregon, the amount of leaf-bearing shale at any one locality is limited, and most of it had been worked over at No. 3748 previous to the leaf count.

Wherever possible a hundred specimens or more were counted at each locality, but in the case of Localities 3927, 3751 and 136 the volume of the leaf-bearing shale was so small that only a few specimens were recorded. The rarer species here have a disproportionately high percentage value in the individual localities, but this is not apparent in totals of the flora as a whole.

Table 2 shows the representation of the species at the 10 localities of the Bridge Creek flora in the Crooked River Basin. In the course of the count, a total of 40 species was noted, leaving unrepresented only 4 species which have been collected there at other times. Certain species previously collected at a locality may not have been recorded there in the course of the leaf count, but in no case would such species hold an important place numerically. The percentages are carried to two places, and third place decimals have been raised in a few cases to make the total for each locality 100 per cent.

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[1] Chaney, Am. Jour. Sci., vol. VIII, 127–44, Aug. 1924.

TABLE 2

| Species | Localities | | | | | | | | | | | | | | | | | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3748 | | 3749 | | 3930 | | 3927 | | 3929 | | 3750 | | 3751 | | 135 | | 136 | | 137 | | | |
| | *No.* | *p. ct.* | *No.* | *p. ct.* | *No.* | *p. ct.* | *No.* | *p. ct.* | *No.* | *p. ct.* | *No.* | *p. ct.* | *No.* | *p. ct.* | *No.* | *p. ct.* | *No.* | *p. ct.* | *No.* | *p. ct.* | *No.* | *p. ct.* |
| Quercus clarnensis | 300 | 55.55 | 223 | 43.22 | 71 | 45.81 | 6 | 24.00 | 84 | 66.14 | 14 | 6.48 | 37 | 46.83 | 64 | 5.36 | 38 | 58.46 | 182 | 64.09 | 1019 | 31.83 |
| Alnus carpinoides | 176 | 32.60 | 267 | 51.74 | 45 | 29.03 | 15 | 60.00 | 34 | 26.77 | 91 | 42.13 | 23 | 29.11 | 204 | 17.07 | 22 | 33.84 | 85 | 29.93 | 962 | 30.05 |
| Typha lesquereuxi | 5 | .93 | | | 1 | .65 | | | | | 1 | .46 | 2 | 2.53 | 792 | 66.33 | 1 | 1.54 | 1 | .35 | 803 | 25.09 |
| Sequoia langsdorfii | 1 | .19 | | | 8 | 5.16 | | | 1 | .79 | 31 | 14.35 | 8 | 10.12 | 53 | 4.51 | | | | | 102 | 3.19 |
| Ulmus brownellii | 20 | 3.70 | 6 | 1.17 | 4 | 2.58 | 1 | 4.00 | 2 | 1.57 | | | | | | | 1 | 1.54 | 11 | 3.88 | 45 | 1.41 |
| Carpinus grandis | 2 | .37 | | | | | | | | | 37 | 17.13 | | | | | | | | | 39 | 1.22 |
| Platanus aspera | 6 | 1.11 | 3 | .58 | 6 | 3.86 | | | 1 | .79 | 3 | 1.39 | 1 | 1.27 | 9 | .75 | 1 | 1.54 | 1 | .35 | 31 | .97 |
| Ostrya oregoniana | 5 | .93 | 1 | .19 | 9 | 5.81 | 1 | 4.00 | | | | | 2 | 2.53 | 2 | .16 | 1 | 1.54 | 1 | .35 | 22 | .69 |
| Acer osmonti | 4 | .74 | | | 2 | 1.29 | | | | | 13 | 6.01 | 1 | 1.27 | | | | | | | 20 | .63 |
| Fraxinus denticulata | 3 | .55 | | | 1 | .65 | | | | | 3 | 1.39 | | | 9 | .75 | | | | | 16 | .50 |
| Myrica diforme | | | | | | | | | | | 3 | 1.39 | | | 13 | 1.09 | | | | | 16 | .50 |
| Pteris sylvicola | | | 1 | .19 | | | | | | | | | | | 14 | 1.17 | | | 1 | .35 | 16 | .50 |
| Celtis obliquifolia | | | 9 | 1.75 | | | | | | | 3 | 1.39 | | | | | | | 1 | .35 | 13 | .41 |
| Salix californica | 1 | .19 | | | 1 | .65 | | | | | | | | | 10 | .83 | | | | | 12 | .37 |
| Umbellularia oregonensis | 4 | .74 | 1 | .19 | | | | | 2 | 1.57 | 3 | 1.39 | | | | | | | | | 10 | .31 |
| Pinus knowltoni | 2 | .37 | | | 2 | 1.29 | | | | | 1 | .46 | 2 | 2.53 | 1 | .08 | | | 1 | .35 | 9 | .28 |
| Grewia crenata | 2 | .37 | | | | | | | | | 3 | 1.39 | 1 | 1.27 | 2 | .16 | | | | | 8 | .25 |
| Juglans oregoniana | | | | | | | | | | | | | | | 7 | .58 | | | | | 7 | .22 |
| Castanea orientalis | | | | | | | | | | | | | | | 6 | .50 | | | | | 6 | .19 |
| Quercus consimilis | | | 2 | .39 | | | | | | | | | | | 4 | .33 | | | | | 6 | .19 |
| Rosa hilliae | 2 | .37 | | | | | | | | | 4 | 1.86 | | | | | | | | | 6 | .19 |
| Ceanothus blakei | | | | | 3 | 1.93 | 2 | 8.00 | | | | | | | | | | | | | 5 | .16 |
| Crataegus newberryi | | | 2 | .39 | 1 | .65 | | | | | 2 | .93 | | | | | | | | | 5 | .16 |
| Corylus macquarrii | | | | | | | | | | | | | | | 3 | .25 | | | | | 3 | .09 |
| Prunus coveus | | | | | | | | | 1 | .79 | | | 1 | 1.27 | | | | | | | 2 | .06 |
| Cyperacites sp. | | | | | | | | | | | | | 1 | 1.27 | 1 | .08 | | | | | 2 | .06 |
| Odostemon simplex | 1 | .19 | | | | | | | 1 | .79 | | | | | | | | | | | 2 | .06 |
| Taxus sp. | | | | | | | | | | | 2 | .93 | | | | | | | | | 2 | .06 |
| Amelanchier grayi | 1 | .19 | | | | | | | | | | | | | | | | | | | 1 | .03 |
| Asarum circularis | 1 | .18 | | | | | | | | | | | | | | | | | | | 1 | .03 |
| Arbutus matthesii | 1 | .18 | | | | | | | | | | | | | | | | | | | 1 | .03 |
| Cercis sp. | | | | | 1 | .64 | | | | | | | | | | | | | | | 1 | .03 |
| Cornus ovalis | | | | | | | | | | | 1 | .46 | | | | | | | | | 1 | .03 |
| Fagus pacifica | | | | | | | | | 1 | .79 | | | | | | | | | | | 1 | .03 |
| Nyssa crenata | 1 | .18 | | | | | | | | | | | | | | | | | | | 1 | .03 |
| Philadelphus bendirei | | | | | | | | | | | 1 | .46 | | | | | | | | | 1 | .03 |
| Platanus condoni | 1 | .18 | | | | | | | | | | | | | | | | | | | 1 | .03 |
| Porana speirii | | | 1 | .19 | | | | | | | | | | | | | | | | | 1 | .03 |
| Rhus praeovata | 1 | .19 | | | | | | | | | | | | | | | 1 | 1.54 | | | 1 | .03 |
| Ulmus speciosa | | | | | | | | | | | | | | | | | | | | | 1 | .03 |
| Totals | 540 | 100.00 | 516 | 100.00 | 155 | 100.00 | 25 | 100.00 | 127 | 100.00 | 216 | 100.00 | 79 | 100.00 | 1194 | 100.00 | 65 | 100.00 | 284 | 100.00 | 3201 | 100.00 |

Only 6 species are represented by more than 1 per cent, *Quercus clarnensis, Alnus carpinoides, Typha lesquereuxi, Sequoia langsdorfii, Ulmus brownellii* and *Carpinus grandis*. These make up 92.79 per cent of the total, leaving only 7.21 per cent to cover the representation of the remaining 34 species. *Quercus clarnensis* and *Alnus carpinoides* together constitute slightly more than two-thirds of the total and are the most abundant species in each locality except No. 135; here *Typha lesquereuxi*, which is rare elsewhere, has the high percentage of 66.33. This locality shows such a different numerical content that it will be considered separately in the discussion which follows. 12 species are represented by only a single specimen, and 4 species by only 2 specimens; clearly the percentages in these cases might not be the same if a larger amount of fossiliferous shale had been worked over, but regardless of the amount of material examined, it seems improbable that any of them would have assumed an important numerical place in the flora. The interpretation of the quantitative data will be considered below in connection with the discussion of the physical indications of the flora.

## PHYSICAL CONDITIONS INDICATED BY THE FLORA

Reference to the correlation table 7 on page 94 brings out the close similarity in species content between the flora from the Gray Ranch and that from the Bridge Creek shales of the John Day Basin. Of the 30 species now listed in the latter, there are only two, *Quercus berryi* and *Ulmus newberryi*, which are not represented in the Crooked River collections; both are of somewhat uncertain status at present, being possibly identical with *Quercus consimilis* and *Ulmus speciosa*, which are present in the floras from both basins. The two floras are clearly of about the same age, and their geographic proximity—the Gray Ranch lies less than 40 miles south of the Allen Ranch locality on Bridge Creek in the John Day Basin—gives basis for the assumption that the conditions under which the forests lived and under which the shales were laid down were much alike in both places.

The physical conditions indicated by the Bridge Creek flora in the John Day Basin have been previously discussed,[1] and only a brief summary need be given here. The climate was temperate and appears to have been characterized by a limited range of temperature and by about 40 inches of rainfall annually. The leaf-bearing shales were laid down in basins of deposition along valleys or at their mouths; the altitude was probably within a few hundred feet of sea-level, and at most was 3,000 feet; the valleys were narrow and deep enough to afford protection to a forest whose living equivalent, the *Sequoia* consociation of the Pacific Coast forest climax—commonly known and referred to as the redwood forest—thrives only under humid conditions.

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[1] Chaney, Carnegie Inst. Wash. Pub. No. 349, No. I, 17–21, 1925.

The relationship between the fossil flora from the Gray Ranch and the modern redwood forest is indicated by the following list, which shows the fossil species which have generic representatives in the modern redwood forest. In this table certain of the living species most closely related to the fossils are not the species of their respective genera now found in association with the redwood; an example is *Alnus tenuifolia* Nutt., the living species most like the fossil *A. carpinoides*, but whose range does not include the Redwood Belt; the alder here is *A. rubra* Bong., a species which is distinct from *A. tenuifolia*, though the two are more nearly related than certain other of the living American species of alder. Likewise, *Odostemon fremontii* Rydb. which has more nearly the form of the fossil *O. simplex* than any other living American species, now lives in the arid regions of the southwest, while the related species, *O. nervosus* Rydb., is the redwood associate. Because of such cases, three columns are included in the list, so that the living species most closely similar to the fossils, as well as their redwood forest representatives, may be indicated.

| *Gray Ranch species:* | *Nearest living species:* | *Redwood Forest species:* |
|---|---|---|
| Abies sp. | Abies grandis Lindl. | Abies grandis Lindl. |
| Acer osmonti Kn. | Acer glabrum Torr. | Acer glabrum Torr.<br>Acer macrophyllum Pursh.<br>Acer circinatum Pursh. |
| Alnus carpinoides Lesq. | Alnus tenuifolia Nutt. | Alnus rubra Bong. |
| Asarum circularis Chaney | Asarum caudatum Lindl. | Asarum caudatum Lindl. |
| Cornus ovalis Lesq. | Cornus nuttallii Aud. | Cornus nuttallii Aud. |
| Corylus macquarrii Heer | Corylus rostrata californica A. DC. | Corylus rostrata californica A. DC. |
| Myrica diforme (Berry) Chaney | Myrica asplenifolia L. | Myrica californica Cham. |
| Odostemon simplex Cockll. | Odostemon fremontii Rydb. | Odostemon nervosus Rydb. |
| Quercus consimils Newb. | Quercus densiflora Hook & Arn. | Quercus densiflora Hook & Arn. |
| Rosa hilliae Lesq. | Rosa nutkana Presl. | Rosa nutkana Presl. |
| Sequoia langsdorfii Heer | Sequoia sempervirens Endl. | Sequoia sempervirens Endl. |
| Taxus sp. | Taxus brevifolia Nutt. | Taxus brevifolia Nutt. |
| Umbellularia oregonensis Chaney | Umbellularia california Nutt. | Umbellularia californica Nutt. |

In addition to these 13 species, which make up nearly one-third of the total of well-defined fossil species, there are many more whose living equivalents characterize the borders of the redwood forest. The following table shows these related border species, with a third column to show the typical redwood associates in cases where the fossils more closely resemble other living species of their genera. Four species are omitted from this discussion because of their inadequate fossil representation or their doubtful generic or specific status. These are *Cyperacites* sp., *Grewia crenata, Platanus condoni* and *Porana speirii.*

| *Gray Ranch species:* | *Nearest living species:* | *Redwood Forest border species:* |
|---|---|---|
| Amelanchier grayi Chaney | Amelanchier alnifolia Nutt | Amelanchier alnifolia Nutt |
| Arbutus matthesii Chaney | Arbutus menziesii Pursh. | Arbutus menziesii Pursh. |
| Ceanothus blakei Chaney | Ceanothus sanguineus Pursh. | Ceanothus thyrsiflorus Esc. |
| Cercis sp. | Cercis occidentalis Torr. | Cercis occidentalis Torr. |
| Crataegus newberryi Cockll. | Crataegus pinnatifida Burge | Crataegus douglasii Lindl. |
| Fraxinus denticulata Heer. | Fraxinus oregona Nutt. | Fraxinus oregona Nutt. |
| Philadelphus bendirei (Kn) Chaney | Philadelphus lewisii Pursh. | Philadelphus lewisii Pursh. |
| Pinus knowltoni Chaney | Pinus radiata Dow. | Pinus attenuata Lem. |
| Platanus aspera Newb. | Platanus occidentalis L. | Platanus racemosa Nutt. |
| Prunus coveus Chaney | Prunus emarginata Walp. | Prunus emarginata Walp. |
| Pteris silvicola Hall. | Pteris aquilina L. | Pteris aquilina L. |
| Quercus clarnensis Trel. | Quercus chrysolepis Liebm. | Quercus chrysolepis Liebm. |
| Rhus merrilli Chaney | Rhus sylvestris S. & Z. | Rhus diversiloba T. & G. |
| Rhus praeovata Chaney | Rhus ovata Wats. | |
| Salix californica Lesq. | Salix lasiolepis Benth. | Salix lasiolepis Benth. |
| Typha lesquereuxi Cockll. | Typha latifolia L. | Typha latifolia L. |

These lists contain practically all the important living species of the Redwood Belt, and the occurrence in the Bridge Creek flora of so large a representation of related fossil species indicates how closely it resembled this modern forest. The absence in the fossil record of the remains of *Pseudotsuga* and *Rhododendron* is worthy of comment, in view of the common occurrence of species of these genera in association with the living redwood—the first named largely on the forest borders and the second in the forest proper. While a careful search for a fossil *Pseudotsuga* both in the Bridge Creek shales at the Gray Ranch and in the John Day Basin localities has yielded no specimens, it can not be stated that this negative evidence is conclusive proof of its absence in this Tertiary forest. The needles are individually deciduous, and even if they were blown or washed into basins of deposition, which would appear to be a rather unlikely occurrence, they would form an inconspicuous part of the record; the cones would be rather more likely to enter the sediments and because of their well-defined characters would surely be recognized if present. Either *Pseudotsuga* was rare or lacking in the Bridge Creek forest of eastern Oregon or, as appears more likely, the trees occupied exposed slopes so far removed from the streams as to contribute no recognizable material to the deposits which have been examined. It is worthy of note that in the count of contemporary plant remains at Muir Woods, where trees of *Pseudotsuga taxifolia* (Lamb) Britt. are common on the upper slopes of the canyon and are present in small numbers in open places along the course of Redwood Creek, neither leaf nor cone material was encountered. The absence in the fossil record of the remains of *Rhododendron* presents quite a different problem. Leaves of the living *Rhododendron occidentale* Gray were fifth in abundance in the count at Muir Woods, where the distribution of this species along the stream border is such as to insure its entrance into the sedimentary record. The leaves are stout enough to make impressions and are sufficiently characteristic to be recognized if present. It has been suggested elsewhere[1] that during the Tertiary this genus, which has its present center of distribution in Asia, may not yet have established itself in North America.

The above lists indicate that approximately three-fourths of the fossil species have living equivalents in and on the borders of the redwood forest of the Pacific Coast. The remaining 13 species, which have no related living representatives in this forest, may be divided into two groups—those whose living equivalents are members of climax forests in other parts of the world, and those whose living equivalents are forest border forms in other parts of the world; these groups are shown in the following lists:

Fossil Species which have Living Equivalents in Other Types of Climax Forests

| *Gray Ranch species:* | *Nearest Living species:* |
|---|---|
| Carpinus grandis Unger | Carpinus betulus L. (Western Europe) |
| Fagus pacifica Chaney | Fagus grandifolia Ehrh. (Eastern North America) |
| Nyssa crenata Chaney | Nyssa sylvatica March. (Eastern North America) |
| Ostrya oregoniana Chaney | Ostrya virginiana K. Koch. (Eastern North America) |
| Tilia sp. | Tilia glabra Vent. (Eastern North America) |
| Ulmus speciosa Newb. | Ulmus montana With. (Western Europe) |

Several of these living species thrive under cultivation in coastal California today. It may be supposed that their elimination from the redwood forest has been due to climatic factors which may be no longer operative and that their return to the Pacific Coast is prevented by present-day barriers to migration.

Fossil Species having Living Equivalents on Borders of Other Types of Forests

| *Gray Ranch species:* | *Nearest Living species:* |
|---|---|
| Castanea orientalis Chaney | Castanea henryi Rehd. (Central China) |
| Celtis obliquifolia Chaney | Celtis douglasii Plan. (Western North America away from the coast) |
| Juglans oregoniana Lesq. | Juglans californica Wats. (Southern California) |
| Quercus cf. ramaleyi Cockll. | Quercus sadleriana R. Br. Campst. (Siskiyou Mountains) |
| Ulmus brownellii Lesq. | Ulmus parvifolia Jacq. (Central and Northern China) |

These four lists, which show the ecological classification of the Bridge Creek flora, may be summarized as follows: (1) There are 13 fossil species with living generic representatives occurring in the redwood forest of California, and 6 additional species whose living equivalents are members of climax forests in similar habitats elsewhere—a total of 19 climax forest species; (2) there are 16 fossil species which have living equivalents growing on the borders of the redwood forest, and 5 additional species whose living equivalents have a similar occurrence on the borders of other forests—a total of 21 forest border species; (3) approximately three-fourths of the fossil species have living equivalents in and bordering the redwood forest; these fossil species include all of the common forms except *Ulmus brownellii;* (4) the remainder have living equivalents in and near other climax forests of eastern North America, eastern Asia, and western Europe.

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[1] **Chaney, Carnegie Inst. Wash. Pub. No. 349, No. I, 14, 1925.**

The above discussion emphasizes the qualitative relationship of the Bridge Creek flora of the Crooked River Basin to that of the John Day Basin, and the close resemblance of both these fossil floras to the living redwood forest. There exist, however, striking differences in the quantitative aspects of the two fossil floras involving certain of the dominant and other species which may best be interpreted as due to environmental causes. Table 3 shows the percentage representation of the more abundant species of each flora and of the species occurring in both floras; because of their abnormal quantitative character, which will be considered below, the data from Locality 135 are not included here with the rest of the Gray Ranch figures.

TABLE 3

| Species | Gray Ranch | Allen Ranch |
|---|---|---|
| | *p. ct.* | *p. ct.* |
| Quercus clarnensis | 47.53 | ............ |
| Alnus carpinoides | 37.78 | 53.75[1] |
| Sequoia langsdorfii | 2.44 | 15.16[1] |
| Ulmus brownellii | 2.24 | ............ |
| Carpinus grandis | 1.94 | .05[1] |
| Platanus aspera | 1.10 | 1.15 |
| Acer osmonti | 1.00 | .68 |
| Ostrya oregoniana | 1.00 | ............ |
| Celtis obliquifolia | .65 | .03 |
| Typha lesquereuxi | .50 | ............ |
| Umbellularia oregonensis | .50 | 8.82 |
| Fraxinus denticulata | .35 | .12 |
| Rosa hilliae | .30 | .05 |
| Crataegus newberryi | .25 | .36 |
| Quercus consimilis | .10 | 8.96 |
| Ulmus speciosa | .05 | 3.08 |
| Quercus berryi | ............ | 4.00[2] |
| | 97.73 | 96.21 |

[1] Leaves and fruits listed separately in Table 2, page 131, Am. Jour. Sci., vol. VIII, Aug. 1924.

[2] Incorrectly listed as *Quercus clarensis* in the same table.

An analysis of Table 3 brings out several important differences between the floras from the two basins. Whereas the four dominant species of the John Day Basin flora, *Alnus carpinoides, Sequoia langsdorfii, Quercus consimilis* and *Umbellularia oregonensis,* make up 86.69 per cent of the total of recorded fossil material, these four species at the Gray Ranch make up only 40.82 per cent; while *Alnus carpinoides* and *Sequoia langsdorfii* are still conspicuous in it, their representation is reduced from 53.75 per cent to 37.78 per cent in the case of the former, and from 15.16 per cent to 2.44 per cent in the latter; *Quercus consimilis* and *Umbellularia oregonensis* which make up nearly 9 per cent each in the John Day Basin flora are reduced to 0.10 per cent and 0.50 per cent respectively in the Gray Ranch flora. *Ulmus speciosa* is also conspicuously reduced from 3.08 per cent to 0.05 per cent. *Quercus berryi* which makes up 4 per cent of the John Day Basin flora has not been certainly recognized in the Crooked River Basin. The less abundant species also vary somewhat in the floras from the two regions.

Taking a dominant place in the Gray Ranch flora is *Quercus clarnensis* with a percentage of 47.53; this species has not been recorded in the leaf counts in the John Day Basin, although its presence in small numbers has been noted in some of the earlier collections. *Ulmus brownellii*, which is not represented in the John Day Basin flora, is also an important species on the Crooked River, making up 2.24 per cent. A consideration of the living equivalents of these two species may serve as a key to the interpretation of the differences between the two floras.

*Quercus clarnensis* is clearly related to the evergreen type of oaks now so common in exposed situations in the Pacific Coast region. Not only are the leaves, with their variation in margin from entire to serrate, highly suggestive of such a species as *Q. chrysolepis*, but there are also *Quercus* fruits which resemble those of the live-oaks of today. *Quercus clarnensis* has displaced *Q. consimilis* in the flora at the Gray Ranch, a change which has great significance when the habits of the two related species of oak are considered. The tan-oak, *Q. densiflora*, which is the living equivalent of *Q. consimilis*, is a regular associate of the redwood, growing widely and at its best in the Redwood Belt. The canyon oak, *Q. chrysolepis*, which is perhaps the most nearly related to *Q. clarnensis* of any of the live oaks of western North America, is not found in the redwood forest proper, but occurs in exposed situations on its borders. It has been noted by the writer on the open stretches of the Eel River a few miles north of Garberville, California, in the heart of the Redwood Belt. The valley here is deep, but the river itself is broad and has open banks; the redwood and its typical associates, which dominate the adjacent forest, find conditions too exposed, and live-oaks and other trees which thrive in open places are found along the stream. Such a habitat may be supposed to have characterized the Gray Ranch locality during the deposition of the leaf-shales and to have made possible the entrance into them of so great a number of the leaves of *Q. clarnensis*.

No elms are found today in the redwood forest or elsewhere in Western North America. However, several species were associated with *Sequoia langsdorfii* during the Tertiary, of which *Ulmus speciosa* was the most common in the John Day Basin. This species is represented by only a single specimen in the leaf count at the Gray Ranch, where its place is taken by the small-leaved *U. brownellii.* None of the living American elms has the simple-serrate margin which characterizes the leaves of this fossil species, but *U. parvifolia* of China has almost identical leaves and its fruits are also similar. This species grows in exposed situations, where the annual rainfall is about 25 inches; if it were present today along the coast of California, it would certainly not be growing in the redwood forest, but rather in the drier situations on its borders or on open adjacent slopes.

The flora from the Gray Ranch contains several other species whose living equivalents are found on the borders of the redwood forest, and which are not found in the Bridge Creek flora at the type locality in the John Day Basin. Of these, *Arbutus matthesii* has its living counterpart in *A. menziesii* which is a typical redwood border tree; *Pinus knowltoni* is related to *Pinus attenuata,* which grows on the margins of the redwood forest; *Pteris silvicola* is hardly distinguishable from *Pteris aquilina,* which lives in open places in redwood and other forests; *Salix californica* is much like *S. lasiolepis* which grows along open stream borders in the Redwood Belt; and *Amelanchier grayi* closely resembles *A. alnifolia* which is a characteristic border species of the redwood and other forests of the West. In addition, *Ceanothus blakei,* which is rare in the John Day Basin fossil localities, has a comparatively wide distribution in the Crooked River Basin; the related living species *Ceanothus thyrsiflorus* is one of the most characteristic species of the redwood forest border.

In Table 4 the floras from the two basins are again compared, this time from the standpoint of their representation in the typical redwood forest group and in the forest border group. No more striking proof can be offered of the general similarity of the two floras than the fact that the total percentage of redwood forest and forest border types is 93.40 at the Gray Ranch and 93.425 at the Allen Ranch. Less than 7 per cent of each flora includes the representation of fossil species whose living equivalents are not found growing in or near the redwood forest. However, the portions of each flora referable to the forest proper and to its borders differ significantly. At the Gray Ranch 9 redwood forest species make up 42.47 per cent of the total, while at the Allen Ranch 8 forest species comprise 87.50 per cent; 15 forest border species make up 50.93 per cent at the Gray Ranch, while the total of this type at the Allen Ranch is only 5.925. With less than half the total of forest forms and nearly 10 times the total of border forms the Gray Ranch flora must be interpreted as representing a more open type of forest than the Allen Ranch flora.

As above mentioned there is a corresponding situation today along the larger streams in the Redwood Belt, where, due to the comparatively open character of these valleys, trees of border types are mingled with the typical forest species and the leaves of both types are subject to entrance into the stream deposits. It should be emphasized that proximity to a basin of deposition is one of the most important requisites to the entrance of material into the fossil record. In the case of the Gray Ranch flora, the valleys may be supposed to have been comparatively open, with an abundance of liveoaks (*Q. clarnensis*) and less numerous pines (*P. knowltoni*), ashes (*F. denticulata*), madroños (*A. matthesii*) and *Ceanothus* growing in such position as to drop their leaves into the streams; the forest proper, made up of typical redwood species, was sufficiently distant from the basins of deposition—a few hundred feet to judge from similar situations in the Redwood Belt—to prevent the entrance in great numbers of the leaves of the redwood (*S. langsdorfii*), tan-oak (*Q. consimilis*) and bay (*U. oregonensis*); and even the representation of the alder (*A. carpinoides*), which like its modern relatives may be supposed to have lived both in the

TABLE 4

| Species | Gray Ranch | | Allen Ranch | |
|---|---|---|---|---|
| | Forest forms | Border forms | Forest forms | Border forms |
| | *p. ct.* | *p. ct.* | *p. ct.* | *p. ct.* |
| Alnus carpinoides | 37.78 | | 53.75 | |
| Sequoia langsdorfii | 2.44 | | 15.16 | |
| Acer osmonti | 1.00 | | .68 | |
| Umbellularia oregonensis | .50 | | 8.82 | |
| Rosa hilliae | .30 | | .05 | |
| Myrica diforme | .15 | | | |
| Odostemon simplex | .10 | | | |
| Quercus consimilis | .10 | | 8.96 | |
| Asarum circularis | .05 | | | |
| Cornus ovalis | .05 | | .07 | |
| Corylus macquarrii | | | .01 | |
| Quercus clarnensis | | 47.53 | | |
| Platanus aspera | | 1.10 | | 1.15 |
| Typha lesquereuxi | | .50 | | |
| Pinus knowltoni | | .40 | | |
| Fraxinus denticulata | | .35 | | .12 |
| Ceanothus blakei | | .25 | | |
| Crataegus newberryi | | .25 | | .36 |
| Prunus coveus | | .10 | | |
| Pteris silvicola | | .10 | | |
| Salix californica | | .10 | | |
| Amelanchier grayi | | .05 | | |
| Arbutus matthesii | | .05 | | |
| Cercis sp | | .05 | | .005 |
| Philadelphus bendirei | | .05 | | .29 |
| Rhus praeovata | | .05 | | |
| Quercus berryi | | | | 4.00 |
| Total percentage | 42.47 | 50.93 | 87.50 | 5.925 |
| Total percentage by localities | 93.40 | | 93.425 | |

forest proper and on its edges, was reduced as compared to the flora on the Allen Ranch in the John Day Basin. Here the predominance of redwood forest forms, of which *Sequoia langsdorfii* alone makes up 15.16 per cent, indicates the close proximity of this forest to the streams and the comparatively narrow character of their valleys.

The varying representation of *Sequoia langsdorfii* in the florules from the different localities at the Gray Ranch may be interpreted as showing that the border zone separating the basins of deposition from the redwood forest proper differed in width from place to place. Table 5 shows that the maximum representation of *S. langsdorfii* is at Locality 3750, where it reaches a total of 14.53 per cent, and that it is wholly lacking in the record at four of the localities. It shows also the unequal representation of the typical border species, *Quercus clarnensis*, at the Crooked River localities. If it be true that the localities with high percentages of *S. langsdorfii* represent situations where the redwood forest approached relatively close to the streams and that localities with low percentages represent situations where a broad border zone intervened, there should be a paucity of the remains of *Quercus clarnensis* where *S. langsdorfii* is numerous, and it should be abundantly represented where *S. langsdorfii* is rare or absent. Table 6 shows that the representation of *S. langsdorfii* is above average at the localities where the representation of *Q. clarnensis* is below average,

TABLE 5

| Locality | Sequoia langsdorfii | | Quercus clarnensis | |
|---|---|---|---|---|
| | Number of specimens | Percentage in this florule | Number of specimens | Percentage in this florule |
| 3750 | 31 | 14.53 | 14 | 6.48 |
| 3751 | 8 | 10.12 | 37 | 46.83 |
| 3930 | 8 | 5.16 | 71 | 45.81 |
| 135 | 53 | 4.51 | 64 | 5.36 |
| 3748 | 1 | .19 | 300 | 55.55 |
| 3929 | 1 | .79 | 84 | 66.14 |
| 3749 | 0 | .............. | 223 | 43.22 |
| 3927 | 0 | .............. | 6 | 24.00 |
| 136 | 0 | .............. | 38 | 58.46 |
| 137 | 0 | .............. | 182 | 64.09 |

TABLE 6

| | Average representation of S. langsdorfii | Average representation of Q. clarnensis |
|---|---|---|
| Locs. 3750, 3751, 3930, 135 | 8.58 | 26.12 |
| Locs. 3748, 3929, 3749, 3927, 136, 137 | .16 | 51.91 |
| All localities | 3.19 | 31.83 |

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and that *S. langsdorfii* is comparatively rare at the localities where *Q. clarnensis* has more than average abundance.

It seems clear from this negative correlation in abundance of these two species, *Sequoia langsdorfii* representing the typical forest group and *Quercus clarnensis* the typical border group, that the border zone varied considerably in width, and that the forest proper closely approached the basins of deposition at several places.

These considerations indicate that the Bridge Creek forest of the Crooked River Basin was essentially the same as that of the John Day Basin, a redwood forest much like that now living in coastal California. The striking differences between the two floras are not in species content, for all of the typical redwood forest species are found in both floras, but rather in their quantitative aspects. The dominance of border types at the Gray Ranch indicates broader streams and more open topography in the Crooked River Basin during the Bridge Creek epoch, resulting in the entrance into the fossil record of large numbers of leaves of the border species which were absent or rare in the narrower valleys where the leaf-bearing shales of the John Day Basin were deposited. There is no basis for the assumption that the differences between the floras from the two basins were due to climatic causes, since the climax formation in each was the same—a redwood forest.

In considering the border character of the Gray Ranch flora, it is essential to distinguish between a marginal flora within a redwood belt, past or present, and one on its southern end. In the former case the border character is due largely to topographic factors, as above described; in the latter it is due to climatic factors. At the southern end of the Redwood Belt of California today, the rainfall is much less abundant than to the north, and as a result the border vegetation is telescoped with that of the forest proper. Redwoods are mingled with oaks, madroños, buck-eyes and willows along the stream borders, and their leaves are entering the stream deposits together. However, several of the typical associates of the redwood are missing, and this combined forest presents a very different aspect than either the typical redwood forest or its border phase at the north. Such a telescoped forest has been recognized in the Mascall flora of the John Day Basin,[1] in which the remains of *Sequoia langsdorfii* are not associated with the typical species of the Bridge Creek flora, but rather with broad-leafed oaks, madroños and other species indicating a dryer habitat.

The florule from Locality 135, which has not been included in the above discussion of the Bridge Creek flora of the Crooked River Basin, has an important bearing on the interpretation of the general physical history. As shown in Table 2 it differs strikingly from all the other collections, both here and in the John Day Basin, in the abundance of the remains of *Typha lesquereuxi,* which make up more than 66 per cent of the total. If any further evidence were required to prove that this locality represents the deposits of a swamp, it would be furnished by the lithologic character of the matrix, which is highly carbonaceous and very thinly and conspicuously bedded. As a result of the high percentage of *Typha,* the representation of the other species is correspondingly diminished in most cases; thus *Quercus clarnensis* which comprises 31.83 per cent of the flora as a whole has here a percentage of 5.36, and the representation of *Alnus carpinoides* is reduced from 30.05 per cent to 17.07 per cent; in the case of *Sequoia langsdorfii,* however, the percentage in this florule is 4.51 as against 3.19 per cent for the flora as a whole. In addition to these four most abundant species, there are only two others, *Myrica diforme* and *Pteris silvicola,* which make up more than 1 per cent of the total at Locality 135.

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[1] Chaney, Carnegie Inst. Wash. Pub. No. 349, No. II, 1925.

With *Typha lesquereuxi* taking so dominant a position it is clear that this florule represents conditions unlike those either of the redwood forest proper or of its open borders. It would appear to indicate a swamp at the edge of the redwood forest, in which the remains of the cat-tails made up a considerable portion of the bottom accumulation, with bordering redwoods, alders and oaks also contributing their leaves. Swamps of this type are said to occur near Eureka, California, along the coastal border of the Redwood Belt. The presence of such a swamp near the base of the section at the Gray Ranch indicates another type of marginal conditions than that of the flora as a whole, no doubt representing deposition near the mouth of a stream, but it is in entire accord with the general conception of a comparatively open type of topography as above outlined.

In view of the presence of an almost identical climax forest in both the Crooked River and the John Day Basins during the deposition of the Bridge Creek shales, as above described, there is no basis for assuming that the climate was in any way different in the two places. Their geographic proximity may in itself be taken to indicate that climatic conditions were uniform over the area in the past as they are today. Any differences between the floras from the two basins may, as above indicated, better be interpreted as due to topographic rather than climatic factors. A redwood assemblage of the type occurring in both basins would be limited to regions in which the temperature was mild and equable and in which the annual rainfall was probably more than 40 inches, and was surely not much if any less.

This part of eastern Oregon is now characterized by rather hot summers and cold winters, the mean annual range in temperature at Prineville being 33.1° F.[1] In the Redwood Belt at Eureka, California, it is only 10.7° F. The rainfall as recorded at Post is 12.44 inches on an 8-year average, and at Dayville, the nearest point to the Allen Ranch locality in the John Day Basin where records are available, it is 11.68 inches on a 15-year average.

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[1] These data on present-day climatic conditions are contained in the Summary of *Climatological Data for the United States,* Sections 16 and 18, U. S. Dept. of Agriculture, Weather Bureau.

The decrease in rainfall and the increased range of temperature in eastern Oregon since the Bridge Creek epoch have resulted in important changes in the plants now living there. Along the Crooked River in the vicinity of the Gray Ranch, the more conspicuous members of the living flora are as follows:

Alnus tenuifolia Nutt.
Betula fontinalis Sarg.
Celtis occidentalis L.
Cornus occidentalis Cov.
Juniperus occidentalis Hook.
Pinus ponderosa Laws.
Populus trichocarpa Torr. & Gray
Ribes aureum Pursh.
Rosa pisocarpa A. Gray
Salix lasiolepis Benth.
Salix sp.
Typha latifolia L.

Away from the river flat, the flora is more sparse, including—

Agropyrum spicatum and other grasses
Artemesia tridentata Nutt.
Cercocarpus ledifolius Nutt.
Chrysothamnus nauseosus (Pallas) Britt.
Juniperus occidentalis Hook.

In the Blue Mountains a few miles to the north, where the rainfall is 15 to 17 inches annually, the flora is much more varied and has many more Bridge Creek elements as pointed out on page 76. The following are some of the most important species:

Abies concolor (Gord.) Parry.
Acer glabrum Torr.
Acer macrophyllum Pursh.
Alnus tenuifolia Nutt.
Amelanchier alnifolia Nutt.
Asarum caudatum Lindl.
Betula fontinalis Sarg.
Ceanothus velutinus Dougl.
Cornus occidentalis Cov.
Corylus rostrata var. californica A. DC.
Crataegus douglasii Lindl.
Juniperus occidentalis Hook.
Larix occidentalis Nutt.
Odostemon aquifolium Rydb.
Philadelphus lewisii Pursh.
Pinus ponderosa Laws.
Populus tremuloides Michx.
Prunus emarginata Walp.
Pseudotsuga taxifolia Britt.
Rhus glabra L.
Ribes aureum Pursh
Rosa pisocarpa A. Gray
Salix lasiolepis Benth.
Sambucus glauca Nutt.
Sorbus sitchensis Roem.
Taxus brevifolia Nutt.
Tsuga mertensiana Sarg.

The contrast between the living and fossil floras of the Crooked River Basin, even when the relatively rich assemblage of the Blue Mountains is included, is quite in accord with the postulated reduction in annual rainfall from 40 inches to 17 inches or less, and with the postulated increase in range of temperature, since the Oligocene.

While no definite statement of the causes for the desiccation of this part of eastern Oregon can here be made, it seems probable that the change has been largely brought about by the folding up of the Cascades, with a corresponding rise in the Crooked River Basin and John Day Basin areas. This would have resulted in the cutting off of much of the moisture from the west, and the consequent aridity would tend to increase the range in temperature. There is no evidence for the presence of an arm of the sea in eastern Oregon during the early part of the Tertiary, since the youngest known marine sediments are of Cretaceous age. The occurrence of a redwood forest in the Oligocene of the Crooked River Basin suggests, however, that such a water body lay to the west without any intervening highlands, and that the orogenic movements above referred to may have been responsible for its withdrawal or at least for its separation by a mountain range from the interior of Oregon.

The importance of secular changes of climate during the Tertiary, and their bearing on the modification of the flora of eastern Oregon from the Bridge Creek epoch to the present, can not be estimated. It is significant to note, however, that during the Oligocene period redwood forests essentially like the Bridge Creek flora of eastern Oregon occupied parts of Switzerland, Greenland, Spitzbergen, Siberia and Manchuria. Clearly some factor of wide-ranging importance has made conditions in these places unsuited at the present time to such a forest, which is now found only in a narrow belt along the coast of California and southern Oregon. Without doubt, emergence and the consequent withdrawal of epicontinental seas have played an important part in the restriction of the redwood forest.

The conditions of sedimentation in the Crooked River Basin during the Bridge Creek epoch may be supposed to have been not unlike those in the John Day Basin[1] except that the streams, at least those portions in which the leaf shales were accumulated, appear to have been larger. The erosional surface on which these shales were laid down, which has been discussed and figured above, may best be considered not to represent a definite interval of erosion, but rather to indicate that the dominantly igneous processes of the Clarno epoch were giving place in large part to erosion. This resulted in the cutting of the valleys whose presence during the Bridge Creek epoch is indicated both by the character of the vegetation and by the stratigraphic relations of the Clarno and John Day formations at the Gray Ranch.

As previously mentioned, the delicate nature of the larger grains of the leaf-bearing shales indicates that these deposits were for the most part or entirely laid down by pyroclastic showers in quiet water. The association with the leaves of the remains of fish and aquatic insects is quite consistent with this idea of the deposition of the leaf shales in water-filled basins along and at the mouths of valleys. The non-fossiliferous portions of the lower division of the John Day beds which make up a predominant part of the series contain more sandy material than the leaf layers, and while much of their content doubtless represents the direct acquisition of pyroclastic material, it may be supposed that erosion from the adjacent Clarno ridges supplied the major portion of it. The absence of gravels in these derived sediments is consistent with their source, since the Clarno tuffs are largely sandy tuffs and during the Bridge Creek epoch, as today, would have broken down to form sands and muds rather than conglomerates. It may be suggested that the characteristic red color of the Lower John Day beds may in part be due to the inclusion in them of material of this color derived from the reddish Clarno tuffs of the Gray Ranch area.

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[1] **Chaney, Carnegie Inst. Wash. Pub. No. 349, No. I, 19, 1925.**

The occurrence of the leaf shales in isolated patches at several levels, as shown by the diagram on plate 7, indicates that conditions favoring the preservation of leaves were not of wide extent laterally nor continuous in time. Restricted as they are to the finer ashy layers of the Bridge Creek shales, the leaves may be supposed to have left their imprints only in the rapidly accumulating ash which fell into the valley bottoms where they grew. On the adjacent ridges the ash fell upon a sub-aerial surface, and any leaves embedded in it may be supposed to have decayed without leaving their impressions. Between periods of eruption, the sediments deposited along the valleys and at their mouths were slightly coarser, due to the erosion of material from the adjacent Clarno ridges, and the preservation of leaves became impossible until another shower of ash fell into the valleys.

The absence of plant remains in most of the Middle and Upper divisions of the John Day Series may be interpreted as being due in part to the cessation of volcanic eruptions which supplied fine ash in which leaf impressions would be readily preserved. Fine material of this sort is almost entirely absent in these divisions, having been noted in the Crooked River Basin only in the butte near Prineville where, significantly enough, the only plant fossils from the Upper John Day beds have been found. There is reason to believe that the paucity of plant remains above the Lower division may also be due in part to an advancement of the erosion cycle, involving the wearing down of the divides and the development of plains. This would have restricted the distribution of the forest, which was of a typical valley type. Merriam and Sinclair[1] have stated that plains and forest types of mammals occur together in the Upper John Day beds. This gives faunal evidence for the supposition that the plains were gradually becoming wider; and the general absence of fossil plants may be interpreted as indicating that the forested areas were becoming restricted. The advance of the prairies upon the forest was doubtless related to the reduction in rainfall which is indicated by the Miocene and Pliocene floras of the northern Great Basin[2] and which will be again referred to in the discussion of the flora from Brinks Ranch.

In summary, the physical setting during the deposition of the Bridge Creek shales in the Crooked River Basin appears to have been

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[1] Univ. Calif. Pub. Bull. Dept. Geol., vol. 5, No. 11, 193, 1907.

[2] Chaney, Carnegie Inst. Wash. Pub. No. 349, No. II, 46, 1925.

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characterized by a topography and a climate wholly unlike those in the region today. As indicated by the geologic relations on the Gray Ranch, large and comparatively deep valleys were cut into the older Clarno tuffs, which stood at an elevation much nearer sea-level than they do today and whose erosion did not produce any large amount of coarse sediments; some of the material of the Lower John Day beds, and probably all that of the leaf-bearing layers, was derived from pyroclastic material either falling directly into the basins of deposition or washed into them from adjacent slopes. Due to the large size of the streams, their margins were occupied by trees of a somewhat different type than those of the redwood forest on the adjacent flats and slopes, resulting in a mixture of leaves of forest and border types. In this respect the flora differs from that of the John Day Basin to the north where the narrower streams and valleys were occupied almost exclusively by trees of the typical redwood forest type. The climate appears to have been essentially like that in the John Day Basin—characterized by a mild and equable temperature and by a rainfall of about 40 inches a year. Subsequent changes in climate and elevation have profoundly changed the character of the flora now living in the Crooked River Basin.

## CORRELATION

The close similarity between the Bridge Creek flora from the Crooked River Basin and from the John Day Basin, which has been mentioned in the preceding discussion, is further emphasized by the relations brought out in the correlation table which follows. Here it is shown that 28 of the Crooked River species, or 63 per cent of the total, are represented in the Bridge Creek flora from the John Day Basin, a number which will doubtless be somewhat increased when the latter is more fully studied. A mere statistical resemblance may represent in itself no final proof as to the likeness of two floras. It is highly significant to note, however, that in this case all but 2 of the 10 most abundant species on the Crooked River are also found in the John Day Basin, where they make up 71 per cent of the total of the specimens recorded there. These same 8 species comprise 93 per cent of the total in the Crooked River Basin, the higher percentage being due to the greater abundance here of *Quercus clarnensis* and *Typha lesquereuxi*.

The Bridge Creek flora in the John Day Basin occurs in shales which appear to be at or near the base of the Lower division of the John Day Series. In the Crooked River Basin, where this division is somewhat thicker, the leaf-bearing shales extend through a vertical range of nearly 500 feet, but there is no evidence of a change in the floras from the bottom to the top of the section; of the 10 most abundant species in the flora as a whole, all but one occur in the uppermost horizon, at Locality 3930. It is therefore assumed that the Crooked River flora is a stratigraphic unit.

In the discussion of the age of the Bridge Creek flora, the evidence from both the Crooked River and the John Day Basins will be used, since the floras from each are essentially the same.

TABLE 7

| Species | Eocene of North America | Bridge Creek Flora of John Day Basin | Florissant | British Columbia | Manchuria | Eagle Creek | Mascall—all localities |
|---|---|---|---|---|---|---|---|
| Acer osmonti |  | X |  |  |  |  |  |
| Alnus carpinoides |  | X |  | X | X | X |  |
| Arbutus matthesii |  |  |  |  |  |  | X |
| Carpinus grandis |  | X | X | X |  |  | X |
| Castanea orientalis |  | X |  |  |  |  |  |
| Ceanothus blakei |  | X |  |  |  |  |  |
| Celtis obliquifolia |  | X |  |  |  |  |  |
| Cercis sp |  | X |  |  |  |  |  |
| Cornus ovalis |  | X |  |  |  |  | X |
| Corylus macquarrii | X | X |  | X | ? |  |  |
| Crataegus newberryi |  | X |  |  |  |  |  |
| Fraxinus denticulata | X | X |  |  |  |  |  |
| Grewia crenata |  | X |  | X |  |  | X |
| Juglans oregoniana |  | X |  |  |  |  | X |
| Myrica diforme |  |  |  | X |  |  |  |
| Nyssa crenata |  |  |  |  |  | X |  |
| Odostemon simplex |  | X |  |  |  |  | X |
| Ostrya oregoniana |  |  |  |  |  |  |  |
| Philadelphus bendirei |  | X |  |  |  | X |  |
| Pinus knowltoni |  |  |  |  |  | X | X |
| Platanus aspera |  | X |  |  |  | X |  |
| Platanus condoni |  | X |  |  |  |  |  |
| Porana speirii |  | X | X |  |  |  |  |
| Prunus coveus |  | X |  |  |  |  |  |
| Quercus clarnensis |  | X |  |  |  |  |  |
| Quercus consimilis |  | X |  | X |  |  | X |
| Rhus merrilli |  | X |  |  |  |  |  |
| Rosa hilliae |  | X | X |  |  |  |  |
| Salix californica |  |  |  |  |  |  | X |
| Sequoia langsdorfii | X | X | X | X | X |  | X |
| Tilia sp |  | X |  |  |  |  |  |
| Typha lesquereuxi |  | X | X |  |  |  |  |
| Ulmus brownellii |  |  | X |  |  |  |  |
| Ulmus speciosa |  | X |  | X |  | X | X |
| Umbellularia oregonensis |  | X |  |  |  |  |  |
|  | 3 | 28 | 6 | 8 | 2 | 6 | 11 |

The age of the Bridge Creek flora was placed as Upper Eocene by Knowlton[1] on the basis of the occurrence of 10 of its species in Eocene formations of North America and because of the assumption of a stratigraphic break between the Bridge Creek shales (Upper Clarno

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[1] U. S. Geol. Surv., Bull. 204, 103–105, 1902.

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formation) and the John Day Series. An analysis of the species listed in Knowlton's correlation table cuts down the number of John Day species occurring in the Eocene to 4, since *Sequoia heerii*, *Juglans schimperi*, *Juglans acuminata*, *Alnus kefersteinii*, *Quercus drymeja*, *Ficus planicostata* and *Rhamnus eridani* are not recognized by the writer as occurring in the Bridge Creek flora, either in the Crooked River or John Day Basins. Of the remaining species, *Sequoia langsdorfii*, *Corylus macquarrii* and *Liquidambar europeum* range from the Eocene into the Miocene, and it is probable that *Fraxinus denticulata* is equally long-lived. In the preceding discussion of the stratigraphy of the Crooked River Basin, the Bridge Creek shales have been stated by the writer to be a part of the Lower division of the John Day Series and to be separated from the underlying Clarno formation by an erosional break. There appears to be no evidence, either floral or stratigraphic, for considering the Bridge Creek flora to be of Upper Eocene age.

In the correlation table a relationship is indicated between the Bridge Creek flora and those from the Tertiary of British Columbia and of Florissant, Colorado. While no recent work has been done on the British Columbia floras, they are generally considered to be of Oligocene age. The age of the Florissant beds has been placed as Oligocene or Miocene, the younger age having been tentatively referred to them by Knowlton[1] who was never inclined to recognize an Oligocene horizon in western America. It is somewhat difficult to compare the Bridge Creek flora with the British Columbia and Florissant floras, since many of their species, while apparently identical with those of the Bridge Creek, have been called by different names. A second correlation table has therefore been prepared, indicating the generic relations of several floras. This brings out an exceedingly close generic similarity between the Bridge Creek and the Florissant floras, and emphasizes its similarity to the British Columbia flora.

Table 7 indicates that two of the Bridge Creek species are found in the shales at Fu-shun, Manchuria, which have been referred to the Oligocene by Florin.[2] The resemblance of the Fu-shun and other Tertiary floras of probably the same age in Siberia is much accentuated by the generic table, which shows that 24 of the 39 Bridge Creek genera occur there.

The Eagle Creek flora has been considered to be of Oligocene age by the writer,[3] due to the intermediate character of its assemblage between the Bridge Creek and Mascall floras of the John Day Basin. The subsequent changing of the age of the Bridge Creek flora from Upper Eocene to Upper Oligocene has resulted in a corresponding

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[1] U. S. Nat. Mus., Proc., vol. 51, 244, 1916.
[2] Geol. Surv. China, Pal. Sin., Ser. A, vol. 1, 34, 1922.
[3] Walker Mus. Contr., vol. II, No. 5, 156, 1920.

TABLE 8

| Genera | Bridge Creek | Florissant | British Columbia | Manchuria and Siberia | Eagle Creek | Mascall |
|---|---|---|---|---|---|---|
| Abies | ......... | ......... | ......... | × | ......... | ......... |
| Acer | × | × | × | × | × | × |
| Alnus | × | × | × | × | × | × |
| Amelanchier | ......... | × | ......... | ......... | ......... | ......... |
| Arbutus | ......... | ......... | ......... | ......... | ......... | × |
| Asarum | ......... | ......... | ......... | ......... | ......... | ......... |
| Carpinus | × | × | ......... | × | ......... | × |
| Castanea | × | × | ......... | × | × | ......... |
| Ceanothus | × | ......... | × | ......... | ......... | ......... |
| Celtis | × | × | ......... | ......... | ......... | ......... |
| Cercis | × | × | ......... | ......... | × | ......... |
| Cornus | × | ......... | ......... | × | ......... | × |
| Corylus | × | ......... | ......... | × | × | ......... |
| Crataegus | × | × | × | × | × | × |
| Cyperacites | ......... | ......... | ......... | ......... | × | ......... |
| Fagus | ......... | × | × | × | ......... | ......... |
| Fraxinus | × | × | ......... | × | ......... | ......... |
| Grewia | × | ......... | × | × | ......... | × |
| Juglans | × | × | × | × | × | × |
| Myrica | ......... | × | × | × | ......... | ......... |
| Nyssa | ......... | ......... | ......... | × | × | ......... |
| Odostemon | × | × | ......... | ......... | ......... | × |
| Ostrya | ......... | ......... | ......... | ......... | ......... | ......... |
| Philadelphus | × | × | ......... | ......... | × | ......... |
| Pinus | × | × | × | × | × | × |
| Platanus | × | ......... | ......... | × | × | × |
| Porana | × | × | ......... | × | ......... | ......... |
| Prunus | × | ......... | ......... | × | × | ......... |
| Pteris | ......... | ......... | ......... | × | ......... | ......... |
| Quercus | × | × | ......... | × | × | × |
| Rhus | × | × | ......... | ......... | ......... | × |
| Rosa | × | × | ......... | ......... | ......... | ......... |
| Salix | ......... | × | × | × | ......... | × |
| Sequoia | × | × | × | × | ......... | × |
| Taxus | ......... | ......... | ......... | ......... | ......... | ......... |
| Tilia | × | × | ......... | × | × | ......... |
| Typha | × | × | ......... | ......... | ......... | ......... |
| Ulmus | × | × | × | × | × | × |
| Umbellularia | × | ......... | ......... | ......... | ......... | × |
|  | 27 | 24 | 12 | 24 | 16 | 17 |

upward shift in the age of the Eagle Creek flora, either to uppermost Oligocene or Lower Miocene. With 6 species and 16 genera common to the Bridge Creek, there is an evident relation between the two floras in spite of the diverse physical conditions under which they lived, as indicated by the absence of *Sequoia langsdorfii* from the Eagle Creek, and the abundance there of the black oak, *Quercus pseudolyrata* Lesq.

While the Bridge Creek and Mascall floras show a marked relationship, both in the numbers of species and of genera in common, the physical conditions indicated by the latter are distinctly unlike those of the Bridge Creek epoch. With its abundance of broad-leafed oaks, the Mascall flora indicates that the annual rainfall was considerably reduced, which is in accord with the general climatic trend in this portion of the Great Basin during the Tertiary.[1]

Summarizing the evidence of the age of the Bridge Creek flora based on a comparison with related floras of western North America and northeastern Asia, it bears its closest resemblance to the Florissant flora, of Oligocene or possibly Miocene age, and to the Oligocene flora of Asia, and has also many points of resemblance to the Oligocene floras of British Columbia. Although there are many points in common between it and the Eagle Creek and Mascall floras, there are differences involving a change in physical conditions which indicate that it is older than these floras.

The occurrence of the Bridge Creek shales in the Lower division of the John Day Series, which underlies without break the Middle division with its well-defined Upper Oligocene fauna, gives support to the reference of the Bridge Creek flora to the Oligocene, probably to *its* Upper portion.

## RELATION OF BRIDGE CREEK FLORA TO TERTIARY FLORAS OF EUROPE AND THE ARCTICS

Of the Bridge Creek species, 22, or half of the total as known from the Gray Ranch, have identical or related species in the Tertiary of Switzerland. Florin has suggested to the writer[2] that the material described by Heer in his *Flora Tertiaria Helvetiae* may be referable to several horizons, ranging in age from Middle Oligocene to Upper Miocene. The Swiss flora contains, of course, a great number of species which have not been noted in Oregon. The following lists indicate the Bridge Creek species which are represented by the same or related forms in the Tertiary of Switzerland:

Carpinus grandis Heer
Grewia crenata (Unger) Heer
Sequoia langsdorfii (Br.) Heer

The following species of the Bridge Creek and Swiss floras appear to be essentially the same:

| *Bridge Creek:* | *Swiss:* |
|---|---|
| Alnus carpinoides Lesq. | Alnus kefersteinii Heer |
| Cornus ovalis Lesq. | Cornus studeri Heer |
| Myrica diforme (Berry) Chaney | Myrica oeningensis Heer |
| Platanus aspera Newb. | Platanus aceroides Heer |
| Pteris silvicola Hall | Pteris oeningensis Unger |
| Salix californica Lesq. | Salix tenera A. Braun |
| Typha lesquereuxi Ckll. | Typha latissima A. Braun |

[1] Carnegie Inst. Wash. Pub. No. 349, No. II, 46, 1925.

[2] Letter of October 12, 1924, in which mention is made of a paper bearing on this problem by Baumberger and Menzel, in Mémoire de la Société Paléontologique Suisse, vol. 40, 1914.

In the following species of the Bridge Creek and Swiss Floras a relationship is suggested:

| *Bridge Creek:* | *Swiss:* |
|---|---|
| Acer osmonti Kn. | Acer trilobatum Sternb. |
| Arbutus matthesii Chaney | Leguminosites sancti-martini Heer |
| Celtis obliquifolia Chaney | Ficus tiliaefolia A. Braun |
| Corylus macquarrii (Forbes) Heer | Corylus insignis Heer |
| Juglans oregoniana Lesq. | Juglans bilinica Unger |
| Ostrya oregoniana Chaney | Ostrya oeningensis Heer |
| Philadelphus bendirei (Kn.) Chaney | Quercus charpentieri Heer<br>Melastomites quinquenervis Heer |
| Prunus coveus Chaney | Prunus acuminata A. Braun |
| Quercus clarnensis Trel. | Quercus lonchitis Unger |
| Quercus consimilis Newb. | Quercus mediterranea Unger |
| Ulmus brownellii Lesq. | Ulmus braunii Heer |
| Ulmus speciosa Newb. | Ulmus fischeri Heer |

While only 3 species are common to the 2 floras, the fact that there are 7 species of the Swiss flora essentially like those of Oregon though with different names, and 12 additional species which show relationships, indicates that the Bridge Creek flora has much in common with the Tertiary flora of Switzerland and that at least a part of the latter may be of the same age, *i. e.* Upper Oligocene.

The Arctic floras of Greenland and Spitzbergen have been called Miocene in age, but it seems probable that here too several horizons are represented, of which the oldest may be Eocene or Oligocene. The following lists show the Bridge Creek species which occur in Greenland and Spitzbergen, as well as species which indicate more or less close relationships.

SPECIES COMMON TO THE BRIDGE CREEK AND ARCTIC FLORAS

| *Bridge Creek* | *Greenland* | *Spitzbergen* |
|---|---|---|
| Carpinus grandis Heer | .. | X |
| Corylus macquarrii (Forbes) Heer | X | X |
| Fraxinus denticulata Heer | X | .. |
| Grewia crenata (Unger) Heer | .. | X |
| Philadelphus bendirei (Kn.) Chaney | X | X |
| Sequoia langsdorfii (Br.) Heer | X | X |

SPECIES OF BRIDGE CREEK AND ARCTIC FLORAS WHICH APPEAR TO BE ESSENTIALLY THE SAME

| *Bridge Creek:* | *Greenland:* | *Spitzbergen:* |
|---|---|---|
| Alnus carpinoides Lesq. | | Alnus kefersteinii Heer |
| Cornus ovalis Lesq. | Cornus hyperborea Heer | |
| Platanus aspera Newb. | Platanus aceroides Heer | Platanus aceroides Heer |

SPECIES OF BRIDGE CREEK AND GREENLAND FLORAS IN WHICH A RELATIONSHIP IS SUGGESTED

| *Bridge Creek:* | *Greenland:* |
|---|---|
| Juglans oregoniana Lesq. | Juglans bilinica Unger |
| Ostrya oregoniana Chaney | Ostrya walkeri Heer |
| Pteris silvicola Hall | Pteris grönlandica Heer |
| Quercus consimilis Newb. | Quercus langeana Heer |
| Salix californica Lesq. | Salix grönlandica Heer |
| Umbellularia oregonensis Chaney | Laurus reussii Ett. |

A total of 15 of the Bridge Creek species, representing over a third of the Gray Ranch flora, have identical or similar representatives in the Arctic floras. Of these there are 6 species which are common to the

Bridge Creek and Arctic floras, 3 species of the Bridge Creek are closely similar to species of the Arctic floras which are called by different names and 6 species show suggestive relationships. It is significant that *Sequoia langsdorfii*, *Alnus carpinoides*, *Quercus consimilis* and *Umbellularia oregonensis*, the Bridge Creek species whose living equivalents are the dominants of the modern redwood forest, all have corresponding or identical species in the Arctic floras.

## SUMMARY

The Bridge Creek flora of the Crooked River Basin, and of the John Day Basin as well, may be considered to be of Upper Oligocene age on the basis of its relations to Oligocene floras of America and Asia, and on the basis of the stratigraphic position of the Bridge Creek shales. A marked resemblance to the Tertiary floras of Switzerland, Greenland and Spitzbergen may be taken to indicate that these floras, in part at least, are also of Oligocene age. Conditions favoring a forest like that in the Redwood Belt of California today appear to have been of wide occurrence in the northern hemisphere during this period.

## SYSTEMATIC DESCRIPTIONS

Of the 44 species making up the Bridge Creek flora as now known from the Crooked River Basin, 41 are here referred definitely to genera, and the descriptions of the remaining 3 are placed at the end of the chapter where the doubtful nature of the generic names applied to them is discussed. All of the genera to which the well-defined forms are referred still have representatives living in North America.

Five of the species whose generic determinations have been satisfactorily made are not represented in the Crooked River collections by material which is adequate to justify giving them specific names. Either the specimens do not possess characters which positively distinguish them from or relate them to other fossil or living species of their genera, as in the case of *Abies* sp. and *Taxus* sp., or they have not been collected in numbers sufficient to make a specific determination possible, as in the case of *Quercus* cf. *ramaleyi*, *Cercis* sp., and *Tilia* sp. The last-named two are, however, represented by much more complete material in the Bridge Creek collections from the John Day Basin, and specific names will be given to them in connection with the study of the floras from this region.

There remain 36 species to which both generic and specific names have been given. In the final placing of these, comparisons with fossil and living related species have been made, both of North America and Eurasia. It seems probable that if a comparison of the Bridge Creek specimens with Heer's types from Switzerland and the Arctics had been possible, some of the species here described as new might have been referred to his fossil species; in the absence of such a comparison, it has not seemed desirable to relate many of the Oregon species to them, in view of the fragmentary nature of so large a number of the figured specimens. Out of the 36 species definitely named, 11 are here described for the first time and 2 more are referred to new generic combinations. Of the 23 previously named species 3 have been described by Heer and one by Unger from Europe and Greenland and the remainder have been described from North America—6 species by Lesquereux, 4 species by Chaney, 3 each by Newberry and Cockerell, 2 by Knowlton, and one by Trelease.

A new species of fern is here described by Mrs. Carlotta C. Hall, whose knowledge of the living ferns of America is proving of great value in the study of this and other fossil Pteridophyte material.

# PHYLUM PTERIDOPHYTA

## ORDER FILICALES

### Family POLYPODIACEAE

### Genus PTERIS Linné

### Pteris silvicola C. C. Hall, new species

(Plate 8, figs. 2, 4–7)

*Description*—Fronds at least pinnate and the pinnae pinnatifid; ultimate rachises up to 1 mm. or more broad; ultimate pinnae to as much as 26 mm. long and 9 mm. wide, distant (up to 12 mm. apart), alternate, sessile or nearly so, not decurrent, spreading at right angles to the rachis or slightly inclined toward the tip, oblong to narrowly oblong, tapering gradually from above the middle to a broad obtuse tip, deeply pinnatifid into several pairs of segments (as many as 5 pairs in our material), and a less deeply divided or entire terminal portion.

Segments rounded or oblong (when oblong the upper margin approximately at a right angle to the midrib, the lower margin extending upward and outward to the apex), obtuse; lower segments sometimes auricled; basal inferior segment arched or inclined toward and away from the rachis with which it forms a wide sinus, basal superior segment lying forward nearly parallel with and close to the rachis; margin entire. Veins free; lower veins of the lower segments dichotomously branched; superior basal vein of each segment running parallel to the midrib of the pinna, the others with one or more forks or simple.

*Discussion*—The determination of this fossil fern as a *Pteris* was made through comparison with a specimen taken from a living plant and sent to the author in 1917 from San Juan Island, Puget Sound, where it grew in a damp and shaded depression. Although in poor condition, fronds of this plant were preserved, as it was not like any specimen of *Pteris* previously seen by the author. One of these, representing Sheet No. 294571 in the herbarium of the University of California, is shown on plate 8, figure 3, for comparison. They are evidently those of a plant affected by its damp and shady environment. They are glabrous and sterile. The segments are short, broad, soft and thin so that the venation is clearly visible. They lacked all stiffness even in the stipe. The roots were planted at Berkeley where they grew under observation for several years and developed fronds which were plainly those of *Pteris aquilina*. The fossil fragments here described can be almost exactly matched in the original material of the San Juan specimens.

*Pteris aquilina* is commonly bipinnate and tripinnatifid or tripinnate and quadripinnatifid. The San Juan specimens of *Pteris* are bipinnate and tripinnatifid, except at the base of one primary pinna where it is clearly tripinnate. From midway

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of the primary pinnae on to their tips the secondary pinnae become gradually reduced in size, and less and less deeply lobed. The fossil specimen of plate 8, figure 6, exhibits this decrease in size and lobing of the ultimate pinnae and we therefore interpret it to be a section of a primary pinna and from near its tip. This makes the fossil species *Pteris silvicola* at least bipinnate and tripinnatifid like many present-day plants of *Pteris aquilina* to which it is certainly very closely related. The ultimate pinnae are alternately placed on the rachis in our fossil material but we may also expect them to be opposite, as both conditions occur on any one frond in all living specimens of *Pteris aquilina* examined by the author.

Finally, the ecologic evidence bears out the foregoing conclusions in a remarkable manner. The associates of this fossil fern were *Sequoia langsdorfii*, *Alnus carpinoides*, *Typha lesquereuxi* and other inhabitants of moist situations. It is not surprising, therefore, that it is most closely approached, not by the forms of *Pteris* now found on dry upland slopes, but by a comparatively rare ecologic type from an exceptionally damp and shady place in the humid northwest.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3749, 135 and 137.

*Collection*—Univ. Calif. Coll. Pal. Bot., Holotype, No. 17, Loc. 3749; Cotype, No. 18, Loc. 3749; Cotypes. Nos. 16, 19, 20, Loc. 135.

# PYLUM SPERMATOPHYTA

## CLASS GYMNOSPERMAE

## ORDER CONIFERALES

### Family PINACEAE

### Genus PINUS Linné

### Pinus knowltoni Chaney

*Pinus knowltoni* Chaney, Walk. Mus. Contr., vol. vi, No. 5, 1920, 160, pl. v, fig. 3, 4; Mason, Carnegie Inst. Wash. Pub. No. 346, 1927, 148, pl. 2, fig. 1, pl. 3, figs. 3, 6, 7.

The remains of this pine are not numerous in the Bridge Creek flora of the Crooked River. For the most part they comprise winged seeds, which have been collected in small numbers at Localities 3748, 3751, 3927, 3930, 135 and 137. A specimen of the foliage comes from Locality 3751.

It may be assumed that *P. knowltoni*, like its living equivalent *P. attenuata* Lemm., was a tree of the open slopes bordering the forest proper. From such a situation few of the leaves, ill suited either for wind or water transportation, would enter the sedimentary record and even the winged seeds would not be largely represented.

### Genus ABIES Link

### Abies sp.

*Abies* sp., Mason, Carnegie Inst. Wash. Pub. No. 346, 1927, 151.

Several specimens with associated needles have been found on the Gray Ranch at the principal locality, No. 3748. In the absence of seeds and cones, it does not seem desirable to definitely indicate their relations to other species of this genus, living or fossil. Among the living species, the needles of *A. grandis* Lindl. are of similar form and size, and a relationship between it and the fossil specimens is suggested. *A. grandis* is a common tree in the moist forests of Western America, its range including the Redwood Belt of coastal California.

### Family TAXODIACEAE

#### Genus SEQUOIA Endl.

#### Sequoia langsdorfii (Brnt.) Heer

*Sequoia langsdorfii* Heer, Fl. Tert. Helv., vol. 1, 1855, 54, pl. XX, fig. 2; pl. XXI, fig. 4.

This species, which is so common in the Bridge Creek flora of the John Day Basin, is comparatively rare on the Crooked River. As elsewhere discussed in this paper, its rarity here appears to be due to the larger size of the streams and the more open nature of the valleys, which resulted in the development of a border type of forest along the margins of the basins of deposition. In this border forest there were some redwoods, but the redwood forest proper was sufficiently removed from the streams to prevent any large accumulation of its leaves and cones in their deposits. Unpublished data collected by the writer in the living redwood forest indicate that the leafy twigs of *S. sempervirens* Endl. are not transported for any considerable distance, since they are rare or absent from stream deposits except in the immediate vicinity of the trees.

Wood of the *Sequoia* type has been recognized and, although it is rather poorly preserved, it appears to be of the *sempervirens* type, and therefore referable to *S. langsdorfii*.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3748, 3750, 3751, 3927, 3929, 3930 and 135.

### Family TAXACEAE

#### Genus TAXUS Linné

#### Taxus sp.

*Taxus* sp., Mason, Carnegie Inst. Wash. Pub. No. 346, 1927, 146, pl. 1, fig. 4.

The remains of *Taxus* are limited to several foliage specimens which do not possess characters sufficient to differentiate them from the living *T. brevifolia* Nutt.

## CLASS ANGIOSPERMAE

## Sub-class MONOCOTYLEDONES

### ORDER PANDANALES

### Family TYPHACEAE

#### Genus TYPHA Linné

#### Typha lesquereuxi Cockerell

*Typha lesquereuxi* Cockerell, Bull. Torr. Bot. Club, vol. 33, 1906, 307.
*Typha latissima* Al. Braun, Lesquereux Rept. U. S. Geol. Surv. Terr., vol. 8, 1883, 141, pl. XXIII, figs. 4, 4*a*. (Not *T. latissima* Al. Braun.)

Remains of *Typha* are especially abundant at Locality 135, making up so large a percentage of the specimens recorded as to indicate that it was growing abundantly at the site of deposition of these somewhat lignitic shales. Elsewhere in the Gray Ranch localities and in the John Day basin it occurs only in small numbers. While only fragmentary remains of leaves have been found, it seems proper to refer them to the Florissant species, which is based upon similarly incomplete material. The interest of the leaves lies in the record of their presence in more or less abundance on the borders of the basins of deposition during the Bridge Creek epoch.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 135, 3748, 136, 3751, 3930, 3750. Near the Ream Ranch 10 miles east of Post, Oregon; Locality 137.

# Subclass DICOTYLEDONES

## ORDER SALICALES

## Family SALICACEAE

### Genus SALIX Linné

### Salix californica Lesquereux

(Plate 8, figs. 8–11)

*Salix californica* Lesquereux, Mus., Comp. Zool., Mem., vol. 6, No. 2, 1878, 10, pl. I, figs. 18 to 20.

This species is described by Lesquereux as being highly variable in shape and as having a short petiole. The leaves from Gray's Ranch are likewise variable, ranging from lanceolate to ovate-lanceolate, or even ovate-oblong. Unlike Lesquereux's specimens, one of these has a petiole 8 mm. long, which is about one-tenth of the length of the leaf blade in this case; however, such a difference does not appear to be of specific rank in fossil specimens where the petiole is frequently broken. In the case of the four leaves figured by Lesquereux, two have incomplete bases from which the petiole is missing. *Salix dayana* Knowlton also appears to be closely related to the Gray Ranch specimens, and may not be distinct from *S. californica.*

As pointed out by Lesquereux, there is a similarity between these fossil leaves and the leaves of the living *S. sessilifolia* Nutt. Their resemblance to *S. lasiolepis* Benth. is perhaps more striking. Both of these willows are found along stream banks in western North America; the latter is of common occurrence in the more open stretches of the streams in the Redwood Belt. No leaves of *Salix* have been found in the Bridge Creek shales of the John Day Basin, where the assemblage of species is such as to indicate typical redwood forest conditions. At the Gray Ranch, however, the occurrence of a few willow leaves is wholly consistent with the more open aspect of the forest.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3748, 3930 and 135.

*Collection*—Univ. Calif. Coll. Pal. Bot., Plesiotypes, Nos. 21, 22, Locality 3748; No. 22, Locality 135; No. 23, Locality 3930.

## ORDER MYRICALES

## Family MYRICACEAE

### Genus MYRICA Linné

### Myrica diforme (Berry) Chaney, new combination

(Plate 9, figs. 1, 3, 5)

*Comptonia diforme* (Sternberg) Berry, Am. Nat., vol. 40, 1896, 495.
*Comptonia columbiana* Dawson, Roy. Soc. Canada Trans., vol. 8, 1890, Sec. 4, 81, text-fig. 10.

The Gray Ranch specimens are clearly the same as that figured as *Comptonia columbiana* by Dawson from British Columbia. Dawson's species has been referred to *Comptonia diforme* by Berry. Since the genus *Comptonia* is not recognized by most botanists as being distinct from *Myrica*, it has seemed best to make a new combination as above indicated.

*M. diforme* is closely related to the living *M. asplenifolia* L., as indicated on plate 9, figures 1 to 5. The range of the living species does not include western America. A related fossil species, *M. oeningensis* Heer, is found in the Tertiary of Switzerland, during which period this type of *Myrica* was clearly more widely distributed than it is at present.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 135 and 3750.

*Collection*—Univ. Calif. Coll. Pal. Bot., Plesiotype, No 27, Locality 135; Plesiotypes, Nos. 25, 26, Locality 3750.

## ORDER JUGLANDALES

### Family JUGLANDACEAE

### Genus JUGLANS Linné

### Juglans oregoniana Lesquereux

*Juglans oregoniana* Lesquereux, Mus. Comp. Zool., Mem., vol. 6, 1878, 35, pl. IX, fig. 10.

Only one incomplete but characteristic specimen is represented in the collections from the Crooked River Basin at Locality 3748. In addition, several specimens of what appear to be the same species of *Juglans* have been secured at Locality 135. This species is common at several of the Bridge Creek localities in the John Day Basin, where it occurs also in the younger Mascall formation.

## ORDER FAGALES

### Family BETULACEAE

### Genus CORYLUS Linné

### Corylus macquarrii (Forbes) Heer

*Corylus macquarrii* (Forbes) Heer, Newberry, U. S. Geol. Surv., Mon. 35, 1898, 61, pl. XXXII, fig. 5; pl. XLVIII, fig. 4.

The present status of this species is somewhat unsatisfactory, and its relation to several other American fossil species is not well defined. Ranging from the Fort Union to the Miocene, and from Alaska to Montana, it may be supposed that it represents an ancestral type of the wide-spread living species, *C. rostrata* Ait. *Corylus rostrata fossilis*, which Newberry also described from the Fort Union,[1] is now considered to be the same as the living species, *C. rostrata;* from Newberry's figures it seems probable that these two fossil species are identical, but without the evidence of the fruits the reference of either to the living species seems hardly justified. The name *C. macquarrii* is given here in preference to *C. rostrata fossilis* because of Knowlton's use of it in his *Fossil Flora of the John Day Basin.*[2]

This species is not common either in the John Day or in the Crooked River Basins. In view, however, of the abundance of the living *C. rostrata* var. *californica* along the streams of the Redwood Belt, and of the small representation of its leaves in the basins along adjacent stream courses,[3] *Corylus macquarrii* may have been a rather common member of the forest during the Bridge Creek epoch without entering more abundantly into the fossil record.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Locality 135.

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[1] Newberry, U. S. Geol. Surv. Mon. 35, 63, pl. XXXII, figs. 1 to 3, 1898.

[2] U. S. Geol. Surv., Bull. 204, 38, 1902.

[3] Chaney, Am. Jour. Sci, vol. VIII, 135, 1924.

### Genus CARPINUS Linné

### Carpinus grandis Unger

(Plate 9, figs. 6–11)

***Carpinus grandis*** **Unger, Synop. Pl. Foss., 1845, 220.**

*Carpinus grandis* is a species described as ranging widely over Europe and North America, and from the Eocene into the Miocene. The differentiation of *Carpinus* and the closely related genus *Ostrya*, on the basis of leaves, is a difficult matter in the case of the living trees, and an equal similarity between the leaves of these two genera may be supposed to have obtained in the Tertiary. The fruits of the two genera are distinctive, and where present as fossils may serve to indicate the occurrence of one or the other genus. In the flora under discussion, however, fruits both of *Ostrya* and *Carpinus* are included in the collections, and it may be considered likely that leaves of both genera should be found in association with them. Rather than refer such leaves arbitrarily to one or the other genus, it has seemed desirable to study the modern leaves in order to determine whether distinguishing generic differences do not exist. In connection with this study, M. K. Eliashevich was the first to suggest a nervation character which appears to differentiate the two genera with a considerable degree of reliability, at least in the case of the modern material available.[1] In *Ostrya* most of the marginal teeth are connected with stout tertiary nerves, of which there may be as many as 5 between the adjacent secondaries near the base; these tertiaries branch off from the secondaries well down toward the midrib, in the basal portion leaving the secondaries as close as a third of the way out from the midrib, and lead directly to all of the marginal teeth except certain of the small ones near the apex. In *Carpinus* the marginal teeth are in most cases definitely connected with tertiaries only in the basal part of the leaf; distally the nerves tend to connect with the teeth irregularly, commonly as branches from percurrent tertiaries; even in the basal region, the tertiaries which run directly to the margin branch off from their secondaries in the outer half or, more commonly, in the outer third of the leaf; these tertiaries are much more slender than is the case in *Ostrya*. A second distinction, which is related to the nervation differences already described, is the character of the leaf margins, which in the case of *Ostrya* are set with teeth of essentially the same size, while in several species of *Carpinus*, especially in the European species, *C. betulus* L., they may be markedly different in size. A third difference has to do with the more slender shape of *Carpinus;* this may also be a function of the tertiary nervation character, which when developed as described in *Ostrya* tends to broaden the leaves. And a fourth difference is in the length of the petiole, which tends to be less in *Ostrya* than in *Carpinus*. An exception may be noted in the case of *Carpinus cordata* var. *chinensis* Franch., in which the tertiary nervation is well developed, the margin is equi-serrate and the shape broad.

The occurrence of the fruit in strobili, which has not been noted in any other species of *Carpinus* but which is characteristic of the genus *Ostrya*, suggests that *C. cordata* var. *chinensis* is an intermediate form between these two genera. Except for it, the nervation distinction above noted holds in all the living material examined, including 18 living species of the two genera. The margin distinction does not hold in all species of *Carpinus*, in some of which the teeth are equi-serrate, and the shape character is somewhat variable within the two genera; the short petiole does not characterize one species of *Ostrya*, *O. carpinifolia*. For the living species of *Carpinus* and *Ostrya*, the criteria as above described serve to distinguish the two genera in the majority of cases.

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[1] The following living species of *Carpinus* and *Ostrya* have been examined in the herbaria of the University of California and of the California Academy of Sciences: *Carpinus betulus* L., *C. caroliniana* Walt., *C. cordata* Blume, *C. cordata* var. *chinensis* Franch., *C. duinensis* Scop., *C. fargesiana* Winkl., *C. henryana* Winkl., *C. intermedian* Wierzb., *C. japonica* Blume, *C. laxiflora* Blume, *C. londoniana* Winkl., *C. orientalis* Mill., *C. polyneura* Franch., *C. twiczaninowii* Hance., *C. viminea* Wall., *Ostrya carpinifolia* Scop., *O. japonica* Sargent, *O. knowltoni* Coville, *O. virginiana* K. Koch.

Applying these criteria to the fossil leaves, it appears that most of the leaves collected in the Crooked River Basin are referable to *Ostrya* rather than to *Carpinus*. The propriety of referring the remainder to *Carpinus grandis* may be questioned; for while it is not possible to distinguish these leaves from the ones figured under this species by Heer from the Tertiary of Europe,[1] the fruits as described below are quite unlike those of *C. grandis*, which have distinctly serrate margins In view of the fact that many American writers have referred similar specimens to *C. grandis*, it is thought best to use that name for the Bridge Creek specimens, pending a study of the American material. It is clear that all of the five Tertiary species of *Carpinus* in America are not distinct, and that a thorough revision is necessary. But it should again be emphasized that while the reference of any particular leaf to one or the other of the two genera may be provisional, and that while the specific name here used for the *Carpinus* material may later be changed, the occurrence of fossil fruits of *Carpinus* and *Ostrya* definitely establishes the presence of both genera in the Bridge Creek flora.

Since the associated fruits of *Carpinus* are the first recorded in America, they are described here. Nut ovoid, 6 mm. in length, conspicuously longitudinally ribbed, bearing at the acute tip the remnants of the calyx, attached at the base to a leaf-like involucre. Involucre 3-winged, the central lobe up to 3.5 cm. long and 0.8 cm. broad, the lateral lobes up to 2 cm. long, attached for as much as half their length to the central lobe, each lobe with a distinct midrib from which numerous branches loop with each other well inside the margin; in some lobes, more commonly the lateral ones, there is a longitudinal nerve on either side of the midrib, extending up for a short distance or nearly to the apex; in one specimen (see plate 9, fig. 9) there are two such nerves on either side of the midrib; margins entire or obscurely serrate.

The leaves of *Carpinus grandis* are similar to those of the common American species, *C. caroliniana* Walt., and to most other living species. The fruits, however, differ from those of *C. caroliniana*, in having the margins of the wings almost or quite entire; in this respect they more closely resemble the European species, *C. betulus* L., and the oriental species, *C. laxiflora* Blume and *C. intermedian* Wierzb. *Carpinus caroliniana* grows on the borders of streams and swamps in eastern North America, ranging southward to eastern Texas and into the mountains of southern Mexico and central America.

*Occurrence*—Leaves have been collected at the Gray Ranch in the Crooked River Basin, 11 miles east of Post, Oregon, at Localities 3748, 3750, 3927 and 3930, and fruits at Localities 3748 and 3930. Leaves and fruits are found also at the type locality on Bridge Creek in the John Day Basin, and leaves occur at several other localities in the John Day Basin, including Localities 3739 and 132 from which specimens have been figured.

*Collection*—Univ. Calif. Coll. Pal. Bot. Plesiotypes, Nos. 29, 30, 31, 33, 34, Locality 3748; Plesiotype, No. 28, Locality 3739; Plesiotype, No. 32, Locality 132.

### Genus OSTRYA Scop.

### Ostrya oregoniana Chaney, new species

(Plate 9, fig. 12; plate 10, figs. 1 to 4)

No fossil species of *Ostrya* have been previously reported from the Tertiary of North America. This may be due not so much to its rarity as to the confusion of its leaves with those of *Carpinus*, of which there are 5 leaf species which are widely distributed in the Tertiary of North America. In the case of the Bridge Creek flora, there is little likelihood that the presence of *Ostrya* would have been noted had it not been for the discovery of several seeds which are clearly of that genus. This has led to an effort to distinguish certain of the leaves as belonging to *Ostrya* also, as discussed above in connection with *Carpinus grandis*. But regardless of the correctness of this separation of the leaves, involving the reference of certain of the leaf specimens to *Ostrya*, the seeds definitely establish the presence of this genus in the Bridge Creek flora. The leaves which are distinguishable from *Carpinus grandis*, together with the associated seeds, are described as follows:

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[1] Tert. Fl. Schweiz, vol. II, 1856, 40, pl. LXXI, fig. 19 *b, c, d, e*; pl. LXII, figs. 2-24; pl. LXXIII, figs. 2-4.

*Description*—Leaves ovate to oblong-lanceolate, with an acute apex which may be extended into a long, slender point, and with the base somewhat rounded, broadly cuneate or cordate, commonly slightly asymmetrical; length 3.2 to 8.8 cm.; width 1.5 to 3.9 cm.; peteole rather stout, up to 7 mm. long; midrib straight, slender; 12 to 15 pairs of secondaries, mostly sub-opposite parallel, leaving the midrib at an angle of about 30°, or at a somewhat higher angle near the base, or on one side in the case of asymmetrical leaves, curving up slightly at the margin where they terminate in the marginal teeth; secondaries giving off 1 to 6 strong tertiary branches from their abaxial sides; these are 3 to 6 in number in the basal half of the leaf, where the inner ones may leave the secondaries one-third to halfway out from the midrib; these tertiaries curve parallel with the secondaries and terminate in the margin; other tertiaries irregularly percurrent; margin sharply serrate, the teeth triangular and long pointed, of essentially uniform size, although those in which the secondaries end may be slightly larger; teeth in practically every case forming the ends of secondaries and tertiaries; texture thin. Fruit—nuts ovoid, about 5 mm. long and 3 mm. wide, in some cases crowned with the remnants of the calyx, commonly loosened from the base of the enclosing involucre prior to fossilization; involucre elongate-oval, narrowed to a short point at the apex, the base truncate or concave at its point of attachment with the stalk of the strobilus, from 1.7 to 2.5 cm. long and 0.8 to 1.1 cm. wide, conspicuously parallel-veined with branches forming a fine network.

In his collections from the Tertiary of Switzerland Heer records leaf and seed material of both *Carpinus* and *Ostrya*. The involucres of his *Ostrya oeningensis*[1] are similar to those from Oregon except that they are smaller; the leaves of this species are more distinctly cordate than those of *Ostrya oregoniana*, and if correctly placed in this genus are surely of a distinct species. It seems possible that certain of the leaf specimens figured by Heer as *Carpinus grandis*,[2] notably figures 19*a* and *d* on plate LXXI, and figures 3, 11, 17, and 22 on plate LXXII, may in reality be the leaves of *Ostrya*, although the presence of associated seeds of *Carpinus* indicates that this genus was also present and was doubtless represented by leaves.

The leaves and fruit of *Ostrya oregoniana* are so similar to those of the living *Ostrya virginiana* K. Koch. as to leave little question as to their close relationship. This species ranges from the Gulf of St. Lawrence westward to Manitoba and the Black Hills, and southward to northern Florida and eastern Texas. It is largely a tree of valley slopes, and has been noted by the writer in ravines in the oak forest of Iowa and Illinois. Its range and habitat are much the same as those of *Carpinus caroliniana* Walt. with which it is commonly associated in the oak forests of the Middle West.

*Occurrence*—Leaves have been collected on the Gray Ranch in the Crooked River Basin, 11 miles east of Post, Oregon, at Localities 3748, 3749, 3751, 3927, 3929, 3930, 135, and 137, and fruits at Localities 3748, 3751, and 136.

*Collection*—Univ. Calif. Coll. Pal. Bot., Type, No. 34, Locality 3748; Paratypes, Nos. 35, 36, 37, Locality 3748; Paratype, No. 38, Locality 136.

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[1] Heer, Tert. Flora Schweiz, vol. 11, 42, pl. LXXIII, figs. 5 to 10, 1856.

[2] Heer, *op. cit.* 40, pl. LXXI, fig. 19*b*, *e*, *d*, 1; pl. LXXII, figs. 2 to 24; pl. LXXIII, figs. 2 to 4; and pl. LXIII, figs. 5 to 10.

If the nervation were completely shown in all these figures, more of the specimens might indicate a relationship to *Ostrya*.

### Alnus carpinoides Lesquereux

(Plate 10, fig. 5)

*Alnus carpinoides* Lesquereux, Rept. U. S. Geol. Surv. Terr., vol. 8, 1883, 243, pl. L, fig. 11; pl. LI, figs. 4, 4*a*, 5.

This is one of the most abundant species of the Bridge Creek flora at all localities, both in the Crooked River and John Day Basins. Its abundant representation in the fossil record clearly indicates that alder trees grew in considerable numbers on the borders of the streams or lakes in which the Bridge Creek shales were laid down.

There is a high degree of variation in the hundreds of leaf specimens which have been collected and studied. This is quite in accord with the variation of leaf form in such closely related species as *A. tenuifolia* Nutt. and *A. alnobetula* Ehrh. as has been elsewhere discussed by the writer.[1] In most specimens the character of the margins has been somewhat altered during the process of fossilization, causing the teeth to have a somewhat more blunt appearance than they may be supposed to have had originally.

Wood from the slopes below locality 3748 includes two specimens of *Alnus;* in the opinion of Professor E. Fritz of the Forestry Department of the University of California these are closely similar in structure to the wood of the living species, *Alnus rubra* Bong., which is an abundant tree of the redwood forest.

*Occurrence*—In the Crooked River Basin at Localities 3748, 3749, 3750, 3751, 3927, 3929, 3930, 135, 136 and 137; also at all of the localities in the John Day Basin.

## Family FAGACEAE

### Genus FAGUS Linne

### Fagus pacifica Chaney, new species

(Plate 10, figs. 6 to 9)

*Description*—Leaves oblong-ovate with an acute tip and a broad cuneate, slightly asymmetrical base; length 5 to 7 cm.; width 2.6 to 3 cm.; petiole stout, curved, 7 to 9 mm. long, present in 4 of the 6 specimens; primary vein medium stout, toward the apex slightly bent at points of attachment of the secondaries; 12 to 14 pairs of secondaries, sub-opposite or alternate, near the base curving up from the midrib at an angle of 30°, and spreading out at an angle of about 45° on one side and of about 55° on the other, in the upper half extending straight out from the midrib to the margin at angles of 45° on one side and of 50° on the other; tertiaries obscure, irregularly percurrent; margin typically simply dentate, the triangular teeth sharp-pointed and directed outward especially in the basal half; texture firm. One apparently abnormal leaf has a blunt apex, and the secondaries leave the midrib at comparatively high angles, 3 of them bifurcating close to their points of attachment and with each branch ending in a marginal tooth; bifurcation of the secondaries is not uncommon among the leaves of *Fagus grandifolia*, the living American species. Another fossil specimen shows several small teeth on the margin which are not related to the secondary nerves; such compound serration, while not characteristic of *F. grandifolia*, is not at all rare; it is present on two of the leaves of sheet No. 5465 in the herbarium of the University of California.

One fruit has been collected. The involucre is 1.7 cm. long and 1.1 cm. wide, on a stout peduncle most of which has been broken off, with slender recurved spines at the distal end. The nuts, 2 or probably 3 in number, are crushed and indistinct, generally ovoid, slender tipped.

Nine fossil species of this genus have been described from the Tertiary of North America, as well as *Fagus americana* (*F. grandifolia* of most authors) from the Pleistocene. Four of these, *F. antipofi*, *F. deucalionis*, *F. feroniae* and *F. macrophylla*, have been first reported from the Tertiary of Europe and occur in the Kenai formation of

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[1] Carnegie Inst. Wash. Pub. No. 349, pt. I, 8 to 10, 1925.

Alaska; *F. antipofi* also is found in the Fort Union at Yellowstone Park, in the Oligocene of British Columbia, and in the Auriferous Gravels at Chalk Bluffs, California; *F. feroniae* is found in the Oligocene of British Columbia and in Miocene at Elko, Nevada. Of the leaves figured as *F. antipofi* by Heer from the Kenai, only one[1] appears to be at all referable to this genus and it is so fragmentary as to present a considerable element of uncertainty; the others[2] are clearly of the *Castanea* type, as is the specimen figured by Lesquereux from the Auriferous Gravels at Chalk Bluffs, California.[3] *F. feroniae*, as figured by Heer from the Kenai[4] and by Lesquereux from Elko,[5] has some resemblance to the living beech, but its generic reference is properly questioned by Lesquereux[6] because of the doubly dentate margins of all of the leaves. I have recently collected leaves which Florin has called *Fagus? feroniae*[7] in the Oligocene shale associated with the coal series at Fu-shun in southern Manchuria. The shape, nervation and other general characters are quite unlike those of any living species of *Fagus*. *F. macrophylla* as figured by Heer from a single incomplete specimen from the Kenai[8] has an entire margin and bears only a slight resemblance to *Fagus*. *F. papyracea* from the Raton of Colorado[9] is of the Castanea type, as is *F. undulata* from the Fort Union of Yellowstone Park.[10] This confusion of *Castanea* with *Fagus* was recognized by Heer, who changed the species *Fagus castanaefolia* to *Castanea ungeri*.[11] He might well have changed several other of his species of *Fagus* to *Castanea* and *Quercus*. The type and only specimen of *F. pseudo-ferruginea* from the Auriferous Gravels at Chalk Bluffs[12] is in the Museum of Palaeontology at the University of California, and while it is suggestive of *Fagus* in shape and general nervation characters, the marginal nervation is wholly different, and the margin itself is entire. *F. lambertensis* from the Pliocene of Alabama is based[13] on a single specimen of a leaf lacking the base; its shape and margin suggests a closer relationship to the living European species, *F. sylvatica*, than to the American species, *F. grandifolia*.

In view of the fact that many of the species of *Fagus* previously reported from the Tertiary are based on fragmentary material or are incorrectly referred to this genus, *F. pacifica* represents one of the few reliable fossil species in America. It appears to be closely related to the living beech, *F. grandifolia*, which is one of the most characteristic trees of the deciduous climax forest of east-central North America, ranging westward into Minnesota and northern Missouri. The beech has its best growth on rich uplands and on the bottom-lands of streams, where the rainfall is 35 to 40 inches annually. It is largely confined to ravines in the westward part of its range, where the rainfall is less abundant. One of its common associates in the eastern forest is *Tsuga canadensis*, the hemlock, which may be considered there to be the coniferous equivalent of the Sequoia in the forest of coastal California. The fossil species, *F. pacifica*, is associated with *Sequoia langsdorfii* in the Bridge Creek shales, and may be supposed to have occupied an environment similar to its living relative. From its restricted occurrence as a fossil, it may be supposed to have been uncommon along the streams and lakes in which the Bridge Creek shales were deposited and, if common at all, to have had its chief distribution on the uplands.

[1] See Heer, Flora Fossilis Arctica, vol. II, abt. 2, pl. V, fig. 4*a*.
[2] *Op. cit.*, pl. VII, figs. 4 to 8, pl. VIII, fig. 1.
[3] Mem. Mus. Comp. Zool. vol. VI, pl. 2, fig. 13.
[4] Flora Fossilis Arctica, vol. II, abt. 2, pl. VI, fig. 9.
[5] U. S. Geol. Surv. Terr., vol. VII, pl. XIX, figs. 1 to 3.
[6] *Op. cit.*, 146.
[7] Pal. Sinica Ser. A, vol. I, Fasc. 1, 12, pl. I, figs. 5 to 7.
[8] Flora Fossilis Arctica, vol. II, abt. 2, pl. VIII, fig. 2.
[9] Knowlton, U. S. G. S. Prof. Paper 101, 297, pl. LXVIII, fig. 1.
[10] Knowlton, U. S. G. S. Mon. 32, pt. 2, 700, pl. LXXXV, figs. 4 to 5.
[11] Flora Fossilis Arctica, vol. II, abt. 2, 32.
[12] Lesquereux, Mem. Mus. Comp. Zool., vol. VI, pl. 2, fig. 14.
[13] Berry, U. S. G. S. Prof. Paper 98, 199, pl. XLVII, fig. 5.

*Occurrence*—Five leaf specimens and the fruit occur at Locality 3748, on the Gray Ranch 11 miles east of Post, Oregon; single leaves come from Localities 3929 and 3749 on the Gray Ranch.

*Collection*—Univ. Calif. Coll. Pal. Bot., Type, No. 43, Locality 3748; Paratypes Nos. 40, 41, Locality 3748; Paratype, No. 42, Locality 3929.

### Genus CASTANEA Adans

### Castanea orientalis Chaney, new species

(Plate 12, figs. 1, 4)

*Description*—Leaves lanceolate, broadest at or just below the middle, caudate-acuminate, gradually narrowing to a slightly asymmetrical cuneate base; length from 11 cm. to probably 20 cm. or more, judging from fragments of larger leaves, width 1.6 to 4 cm.; average dimensions 14 by 2.6 cm.; petiole stout, about 1.5 cm. long in specimens of average size; midrib heavy, slightly curving toward the apex; 20 or more pairs of secondaries, mostly sub-opposite, leaving the midrib at an angle of about 45°—more basally and less apically, and curving up gradually to terminate in the marginal teeth; in one case a secondary is forked, each branch ending in a tooth as is occasionally the case in the leaves of living chestnuts; tertiaries irregularly percurrent, with transverse nerves and nervilles forming a coarse network; a strong tertiary branches off from the axial side of each secondary just inside the margin and forms loops with two or more abaxial tertiaries from the secondary next above; margin dentate except at the base, the teeth triangular and produced into slender, rather bluntly-tipped spines; texture firm.

The strong tertiary nerve branching axially near the margin appears to be a distinguishing character for *Castanea* and *Castanopsis*, both as regards the living and fossil species. In *Fagus* and the chestnut-oak type of *Quercus*, a similar tertiary nerve may be present, but in the case of none of the modern material observed is it as stout as in *Castanea*, where it is of practically the same size as the outer end of the secondary from which it branches. Another distinction is the angle of branching of this tertiary nerve, which approaches 90° in *Castanea* and *Castanopsis*, and is ordinarily much less in the other two genera.

None of the four leaf species described from the Tertiary of North America is closely related to *C. orientalis*, all of them having the more ovate shape which characterizes the living North American species, *C. dentata* Borkh. and *C. pumila* Mill. In most of the fossil specimens figured, there is the further distinction of the secondaries being comparatively straight, whereas in *C. orientalis* they curve up to the margin.

Among the living species of *Castanea*, *C. orientalis* is much like the slender leaves of *C. crenata* S. & Z. of Japan and Korea (see sheet 115507 in the herbarium of the California Academy of Sciences). It bears an even more striking resemblance to *C. henryi* Rehd. of central China. Certain of the leaves of this species tend to have a more lanceolate shape than any other living species observed and, in this slender type of leaf, the secondary nerves are curved as in the fossil species. A difference is the somewhat greater distinctness of the teeth of *C. orientalis* due to their being broader at their bases; in *C. henryi* the teeth may be little more than a spine from a slight bulge in the margin opposite the ends of the secondaries. The spines are longer than those of the fossil species, in which they may have been broken off in connection with their deposition in the sediments. The fact that *C. henryi* was originally referred to *Castanopsis*,[1] and that according to Sargent[2] it resembles this genus closely except in features which have no relation to leaf form, suggests that it may be an intermediate species, and that both it and the related fossil, *C. orientalis*, are of a comparatively primitive type. A leaf of *C. henryi* on sheet 259035 from Wang Shan, Anhwei Province, China, in the herbarium of the University of California, is figured on plate 12 to show its close resemblance to *C. orientalis.*

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[1] *Castanopsis henryi* Skan., Jour. Linn. Soc., vol. xxvi, 523, 1899.

[2] Sargent, Plantae Wilsonianae, vol. iii, 196, 1916.

The habitat given on this sheet—"foot of mountain"—suggests that the tree grew in a situation like that of the American species, *C. dentata,* which is most commonly found in the hills of the Appalachian region and of the glacial drift. A similar habitat in the case of *C. orientalis* would account for its comparatively small representation in the Bridge Creek flora.

No fruits of *Castanea* have been noted either in the Crooked River or the John Day Basins, but remains doubtfully referred to this genus have been collected in the closely related Eagle Creek formation in the Gorge of the Columbia River, some 130 miles to the northwest.[1]

*Occurrence*—In the Crooked River Basin on the Gray Ranch, 11 miles east of Post, Oregon, at Localities 3748 and 135, and in the John Day Basin on Cant's Ranch at Locality 3931.

*Collection*—Univ. Calif. Coll. Pal. Bot., Type, No. 58, Locality 3931; Paratype, No. 59, Locality 3748.

### Genus QUERCUS Linné

### Quercus clarnensis Trelease

(Plate 10, figs. 10 to 13; plate 11, figs. 1 to 7, 9, 10)

*Quercus clarnensis* Trelease, Brooklyn Bot. Gard., Mem. I, 1918, 499.

*Fraxinus affinis* Newberry, U. S. Nat. Mus., Proc., vol. 5, 1883, 510; U. S. Geol. Surv., Mon., vol. 35, 1898, 127, pl. XLIX, fig. 5.

*Quercus affinis* (Newberry) Knowlton, U. S. Geol. Surv., Bull. 204, 1902, 45.

*Quercus furcinervis* Rossm. Lesquereux, Rept., U. S. Geol. Surv. Terr., vol. VIII, 1883, p. 244, pl. LIII, figs. 10 to 12.

*Quercus breweri* Lesquereux, Rept. U. S. Geol. Surv. Terr., vol. VIII, 1883, pl. LIV, fig. 9 (not other figures).

As indicated in the above synonymy, this species of oak has been called by several names and has even been referred to the genus *Fraxinus.* A complete account of its nomenclatorial history has been given by Knowlton,[2] and the writer is in complete agreement with him in his reference of it to a new combination. In view of the preemption of the specific name *affinis,* Trelease has used the new name *clarnensis.*

*Quercus clarnensis* is the most abundant species of the Bridge Creek flora in the Crooked River Basin, but is rare or absent at most of the localities in the John Day Basin. Oddly enough it is represented almost entirely by leaves, only about 5 acorn cups and a few staminate aments having been noted. In view of the large amount of new material at hand, and of its high degree of variability, it is thought desirable to re-describe the species here.

*Description*—Leaves ovate-lanceolate to obovate-lanceolate, or in the case of smaller specimens lanceolate, gradually narrowing to a cuneate base or more commonly bluntly cuneate, in some cases distinctly rounded, the tip varying from abruptly acuminate (in obovate individuals) to elongate-acuminate and slightly falcate; length from 2.6 to 9.1 cm.; width from 0.7 to 2.9 cm.; average dimensions of the ovate-lanceolate and obovate-lanceolate type 2 by 5.9 cm. (see fig. 6, pl. 10), and of the lanceolate type 1 by 4.2 cm. (see fig. 12, pl. 11); petiole short and stout, in some specimens slightly twisted, averaging 4 or 5 mm. long; midrib stout near the base and gradually becoming slender at the apex; 12 to 15 pairs of slender secondaries, sub-opposite, leaving the midrib at an angle as high as 80° near the bases of the broader specimens and as low as 45° toward the tips, and in the lanceolate specimens terminating in the marginal teeth or, in the basal entire portions of the leaves, looping with the pair next above; finer nervation in most cases indistinct, forming an irregular network; margin commonly undulate, serrate in the upper half or less commonly in the upper three-fourths, rarely entire except for a few teeth scattered along one side; the teeth quite variable in shape (due in part no doubt to accidents of preservation), bluntly triangular to elongate-acute, pointing upward or more rarely outward, in a few specimens recurved, and in some cases at least bearing a short spine; texture sub-coriaceous. There are several specimens of twigs with two or more leaves attached, one with several branchlets bearing 9 leaves, and another terminal twig with a rosette of 4 leaves.

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[1] Chaney, Univ. Chicago, Walker Mus. Contr., vol. II, No. 5, 166, pl. X, figs. 3 to 5, 1920.

[2] Bull. U. S. Geol. Survey, 204, p. 45, 1902.

Acorn-cups rather shallow and apparently sessile, covered with triangular, closely appressed scales, about 2 cm. in diameter. Staminate aments rather short and stout, badly crushed in all the specimens; calyx with 6 or 7 broadly ovate lobes.

The leaves of *Q. clarnensis* can be readily distinguished from typical leaves of *Q. consimilis*, the other common oak of the Bridge Creek flora, by their smaller size, their more slender shape and their tendency toward obovateness. The teeth on the margins are more slender and less regular in direction than those of *Q. consimilis*. The distinction between *Q. clarnensis* and *Q. berryi* can be made on the basis of shape, the latter being much longer and more slender.

None of the living species of American oaks appear to be closely related to *Q. clarnensis*. The fossil leaves of the ovate-lanceolate and obovate-lanceolate types resemble certain of the leaves of *Q. tomentella* Engelm. and *Q. oblongifolia* Torr. and show a marked likeness to some of the smaller leaves of *Q. engelmannii* Greene (see sheet No. 5498 in the herbarium of the University of California). The more lanceolate types of *Q. clarnensis* are closely similar to certain of the leaves of *Q. chrysolepis* Liebm., especially the smaller shade-leaves of the trees of this species growing on the borders of the redwood forest along the Eel River in Humboldt County, California; but in general the leaves of *Q. chrysolepis* are much broader and their marginal teeth are larger and blunter. The fossil acorn cups rather closely resemble those of *Q. chrysolepis*. *Q. clarnensis* may well have been the ancestor of several of the living species of American oaks, some of which, as *Q. tomentella*, *Q. oblongifolia* and *Q. engelmanni*, have spread out into habitats quite unlike that which the fossil species may be supposed to have occupied.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3748, 3749, 3750, 3751, 3927, 3929, 3930, 135, 136 and 137.

*Collection*—Univ. Calif. Coll. Pal. Bot., Plesiotypes, Nos. 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54; Locality 3748.

### Quercus consimilis Newberry

*Quercus consimilis* Newberry, U. S. Geol. Surv., Mon. 35, 1898, 71, pl. XLIII, figs. 2 to 5, 7 to 10.

This species is one of the dominants of the Bridge Creek flora in the John Day Basin, but at the Crooked River localities it is rare or absent. This difference in representation may probably be explained in terms of habitat difference, in the consideration of which a closely related modern species, *Quercus* (*Lithocarpus*) *densiflora* Hook. & Arn., the tan-bark oak, furnishes valuable suggestions. The tan-bark oak is a close associate of the redwood in the coastal forest of California, reaching its largest size and greatest abundance there. It follows that its Tertiary equivalent, *Q. consimilis*, should be common in the shales of the John Day Basin where *Sequoia langsdorfii* makes up so important an element of the flora. But in the localities at the Gray Ranch, as stated above, *S. langsdorfii* is inconspicuous or lacking, which indicates a forest of a modified type. Here *Quercus clarnensis* is the most abundant oak, a species related to several living oaks of the live-oak type which live in more exposed situations than are characteristic of *Q. densiflora*. Clearly the more open type of forest in the Crooked

River during the Bridge Creek epoch, as shown especially by the paucity of the remains of *Sequoia*, favored the presence of trees of the live oak rather than the tan-oak type.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3748, 3749 and 135.

### Quercus cf. ramaleyi Cockerell

(Plate 11, fig. 8)

*Quercus ramaleyi* Cockerell, Bull. Torr. Bot. Club, vol. 33, 1906, 309, text-fig. 2.

A single specimen of an oak closely related to Cockerell's species from the Florissant Beds has been collected. While it is not possible on the basis of so little material to finally establish its relationships, there can be no question as to its distinctness from the common oak of the flora, *Q. clarnensis*, and from *Q. consimilis.*

Among living species, this specimen bears a suggestive resemblance to *Q. sadleriana* R. Br. Campst., which now occupies the mountain slopes of southwestern Oregon and northern California. If the Bridge Creek species had a similar habitat, the paucity of its representation in the fossil flora may be readily explained.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Locality 3930.

*Collection*—Univ. Calif. Coll. Pal. Bot., No. 56, Locality 3930.

## ORDER URTICALES

## Family ULMACEAE

### Genus ULMUS Linné

### Ulmus brownellii Lesquereux

(Plate 12, figs. 3, 6, 7, 8; plate 13, figs. 1, 3, 4, 6)

*Ulmus brownellii* Lesquereux, U. S. Geol. Surv. Terr., vol. 8, 1883, 160, pl. XXVIII, figs. 2, 4.
*Ulmus hilliae* Lesquereux Cockerell, Am. Nat., vol. 44, 1910, 40, fig. 5.
*Myrica callicomaefolia* Lesquereux, U. S. Geol. Surv. Terr., vol. 8, 1883, 146, pl. XXVI, figs. 5 to 14.
*Myrica drymeja* (Lesq.) Knowlton, Cockerell, Am. Nat., vol. 44, 1910, 42, fig. 6.

*Ulmus brownellii*, which is represented by numerous leaves and fruits at the Gray Ranch localities, is unique among American species of its genus, both fossil and living, in having a simple-serrate margin. It is much like *Ulmus hilliae* Lesquereux, but this species if correctly described and figured by Lesquereux[1] has some double-serrate teeth. As indicated in the above synonymy, the specimens of *Ulmus hilliae* figured by Cockerell are of the *brownellii* type. I have been unable to find any living representative of the genus *Myrica* whose leaves have the shape, nervation and margin characters of these specimens. On the other hand, both my material and that of Lesquereux, is practically identical with *Ulmus parvifolia* Jacq. of northern China, as regards both the leaves and the seeds. It is therefore necessary to refer the leaves figured as *Myrica callicomaefolia* by Lesquereux and as *Myrica drymeja* by Cockerell (the other citations of this species are not so referable) to *Ulmus brownellii.* The description follows:

*Description*—Leaves ovate to ovate-lanceolate, small specimens lanceolate; in some cases falcate, gradually narrowing to a slender tip, which may be attentuate, the base broadly or more rarely narrowly cuneate, distinctly asymmetrical in most specimens, being slightly rounded on one side and obliquely angled on the other; length 2 to 6.9 cm.; width 0.6 to 2.4 cm.; average dimensions 4.7 by 1.8; petiole stout, slightly curved, commonly less than 0.5 cm. long; midrib regularly curving toward the apex; secondaries sub-parallel, more numerous on the side with the rounded base where they are 12 to 22 in number, leaving the midrib at an angle of 55° or more and curving up slightly to end in the marginal teeth, with small branches running down near the margin to the corresponding sinuses; on the side with the oblique base, secondaries 10 to 18 in number, leaving the midrib at an angle of 30° to 50°; tertiaries distinct, forming a fine network; margin simple-serrate, the teeth abruptly narrowed to form a sharp tip, pointing outward in the basal portion and upward in the apical portion, texture firm but not thick. Fruit a circular to ovate samara with a deeply notched apex, the margin entire, length 8 to 10 mm., width 7 to 8 mm.; seed ovoid.

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[1] Rept. U. S. Geol. Surv. Terr., VIII, 1883, 160, pl. XXVIII, figs. 1, 3.

Of the 30 fossil species of *Ulmus* described from North America, there is none which bears any close resemblance to *U. brownellii*, the chief points of difference being its simply serrate margin and small size. Similarly none of the species of *Ulmus* now living in North America appears to be closely related to this fossil species, all having doubly serrate margin and with few exceptions being larger. *Ulmus plurinervia* Unger, figured by Heer from the Tertiary of Switzerland,[1] of Greenland[2] and of Sachalin[3] has a simply serrate margin, but its somewhat different shape makes it doubtful whether it represents the same species as *U. brownellii*. Several of the specimens figured as *Planera ungeri* by Heer[4] appear to be identical with *U. brownellii* and their reference to *Ulmus* rather than to *Planera* is indicated by the branches from the secondary nerves which run down near the margin to the sinuses between the teeth, as well as by their shape and the character of their margins.

The great similarity between *U. brownellii* and *U. parvifolia* now living in northern China and Japan has been pointed out and emphasizes the relationship between the Bridge Creek flora and the living flora of northeastern Asia as elsewhere discussed. The coriaceous texture of the leaves of the living tree is related to the somewhat arid conditions under which it lives. Even in the vicinity of Peking where the rainfall is 25 inches annually the trees are small and their leaves thick. Its present distribution is suggestive of relictivity, a suggestion which is supported by the occurrence of so closely a related species as *U. brownellii* in the Tertiary of North America. While the leaf texture of the latter species is not so thick as that of its living relative of Asia, the scarcity of its leaves in all but one of the localities (this being No. 3748 where *Sequoia* is practically absent and where *Quercus clarnensis* is the dominant) indicates that it had a somewhat similar habitat, being a tree of the borders or adjacent ridges rather than a member of the redwood forest proper.

*Occurrence*—In the Crooked River Basin on the Gray Ranch, 11 miles east of Post, Oregon; leaves at Localities 3748, 3749, 3927, 3929, 3930, 136 and 137, and fruits at 3930 and 3748.

*Collection*—Univ. Calif. Coll. Pal. Bot., Plesiotypes, Nos. 60, 61, 62, 63, 65, 66, 67, Locality 3748; Plesiotype, No. 68, Locality 3930.

### Ulmus speciosa Newberry

(Plate 12, fig. 5)

*Ulmus speciosa* Newberry, U. S. Geol. Surv., Mon. 35, 1898, 80, pl. XLV, figs. 2 to 4, 7.

This species is common in the John Day Basin, but only a few specimens have been found in the Crooked River Basin. Its place here is taken by the small-leafed *Ulmus brownellii Lesquereux*, a less mesophytic type which is better suited to this comparatively open type of forest. Both the leaves and fruits resemble those of the living European species, *U. montana* With., more closely than any of the American species, although a relationship to *U. fulva* Michx. is also apparent.

[1] Heer, Tert. Fl. Schweiz., vol. II, 58, pl. LXXIX, fig. 4.
[2] Heer, Fl. Foss Arct., vol. 7, pt. 2, 93, pl. LXXXIX, fig. 8.
[3] Heer, Fl. Foss. Arct., vol. 5, pt. 4, 8, pl. 2, fig. 5.
[4] Heer, Tert. Fl. Schweiz., vol. 2, 60, pl. LXXX, especially figs. 3, 11, 14, 16, 17.

A specimen of wood from the slope below Locality 3748 has been studied by F. H. Frost, who has suggested its resemblance to the living *U. americana* L. It has not been possible to compare this fossil specimen with the wood of *U. parvifolia* Jacq., the living species to which the fossil leaf species, *U. brownellii,* is related. It seems somewhat more likely, from the greater abundance of *U. brownellii* that any wood occurring at the Gray Ranch would be referable to it rather than to the comparatively rare *U. speciosa.* However, the specimen is mentioned under the heading of *U. speciosa,* not because any definite relationship between the foliage and stem material has been established, but because this species is more nearly of the type of *U. americana,* to judge from its leaves and fruits.

*Occurrence*—A leaf was recorded at Locality 136, the Gray Ranch, and the fruit here figured comes from Locality 3748 nearby.

### Genus CELTIS Linne

### Celtis obliquifolia Chaney

(Plate 13, fig. 12)

***Celtis obliquifolia*** **Chaney, Carnegie Inst. Wash. Pub. No. 349, pt. III, 1925, 51 to 53, pl. I, figs. 1, 3, 5.**

This species is relatively rare, making up only 0.41 per cent of the total number of fossil specimens recorded at the Gray Ranch, and only 0.03 per cent at the type locality on Bridge Creek in the John Day Basin. Its greater representation at the Gray Ranch is wholly in accord with the suggestion that it was not a typical member of the redwood forest but was rather a border form, for the border type of vegetation is much better represented here than at the John Day Basin localities.

A closely related living species, *C. douglasii* Plan., is now found commonly along the stream courses in eastern Oregon, occurring within a few miles of the fossil localities. Its leaves are much smaller and thicker than those of the fossil species, which is in accord with the evidence of reduction in rainfall in this region since the Oligocene. Of all the Bridge Creek types which have persisted in eastern Oregon since the Tertiary, *C. douglasii* is perhaps the best adapted to this highly altered habitat.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3748, 3749, 3750, 3929. Near Reams Ranch, 10 miles east of Post; Locality 137.

*Collection*—Univ. Calif. Coll. Pal. Bot., Plesiotype, No. 73, Locality 137.

## ORDER ARISTOCHIALES

## Family ARISTOLOCHIACEAE

### Genus ASARUM Linné

### Asarum circularis Chaney, new species

(Plate 13, fig. 11)

Leaves cordate-reniform, obtusely pointed or rounded at the apex which is not completely preserved in any of the specimens, the basal lobes extending down as much as a centimeter from the point of attachment with the petiole, nearly or slightly overlapping; length 4.5 to 6.5 cm., width 4.3 to 6.4 cm.; nervation distinct, with a central and 4 pairs of lateral primaries which branch dichotomously one or more times and also give off secondaries, forming well-defined loops near the margin; margin broadly undulate and with small irregularities; texture thin.

No representatives of the genus *Asarum* have been previously reported from the Tertiary of America. The growing habit of the living members of the genus offers ample explanation for its rarity among fossil floras. Although *A. caudatum* Lindl., the living counterpart of *Asarum circularis*, is one of the most abundant plants of the stream flats in the redwood forest, its leaves enter the stream deposits in exceedingly low numbers, due to the lack of any definite deciduous habit and to the low stature of the plants, which gives little opportunity for transportation by wind of such leaves as become loosened.

In a count of over 8,000 leaves in the contemporary deposits along Redwood Creek, Marin County, California,[1] only one leaf of *Asarum caudatum*, comprising 0.01 per cent of the total, was encountered, although the species is extremely common along the course of the stream, growing within a few feet of its banks In the course of a recent count of the fossil leaves at the Gray Ranch, one leaf of *Asarum circularis* was found among 3,201 specimens recorded, comprising 0.03 per cent of the total. Judging from these percentages of representation, the fossil species might be supposed to have been even more abundant in the Bridge Creek plant formation than is the living *A. caudatum* in the redwood forest, where as above stated it is one of the most abundant herbaceous plants. Clearly the number of specimens of fossil herbaceous types gives only an imperfect idea as to the actual representation of a species in a fossil flora, much as the single leaf of the living species, *A. caudatum*, might have given rise to a misconception as to its abundance in the modern forest if actual observations of the living plants were not possible.

*Occurrence*—Of the 5 specimens found, 3 are recorded from the Gray Ranch, 11 miles east of Post, Oregon, Locality 3748, and the remainder are from the Clarnos Ferry Locality, No. 3739, in the John Day Basin.

*Collection*—Univ. Calif. Coll. Pal. Bot., Type, No. 72, Locality 3748.

## ORDER RANALES

### Family BERBERIDACEAE

### Genus ODOSTEMON Rafinesque

### Odostemon simplex (Newb.) Cockerell

(Plate 14, figs. 7, 8, 9, 11)

*Berberis simplex* Newberry, U. S. Geol. Surv. Mon. 35, 97, pl. LVI, fig. 2.
*Odostemon simplex* (Newb.) Cockerell, Am. Mus. Nat. Hist., Bull., vol. XXIV, 1908, 91.

Except for the type specimen collected by Condon more than 60 years ago, this species has never been encountered until it was found by the writer in the Payette formation of Idaho several years ago.[2] It has been collected more recently in the Bridge Creek shales at several localities in the Crooked River and John Day Basins. Since the new material shows nervation characters which are obscure in the type specimen, the following description is written to supplement that of Newberry.

*Description*—Leaflets ovate to ovate-lanceolate, conspicuously lobate-dentate, with an acute and commonly attenuate apex, the base asymmetrical, broadly cordate to broadly cuneate; length 2.9 to 5.4 cm.; width 2.2 to 3.4 cm.; nervation palmate, the midrib stout and persistent to the apex, 2 or 3 pairs of lateral nerves branching off from the base and joining irregularly with secondaries to terminate in the teeth in the basal portion of the leaflet; stout secondaries branching off from the midrib and the lateral primaries, and joining with other nerves to terminate in the teeth; tertiaries few, forming loops joining the secondaries with each other and with the lateral primaries; nervilles indistinct in most specimens, forming a fine polygonal network; margin with 3 pairs of lobate teeth, less commonly 4 or 5 pairs, triangular or more commonly attenuate, produced into a long spine at the tip; texture coriaceous as indicated by the thickened margin, the faint preservation of the finer nervation in most specimens, and the undulate character of the leaflets which are distinctly twisted down at their point of attachment with the rachis. The number of leaflets on the leaves is unknown, due to the general occurrence of this species as isolated leaflets. The type specimen, as figured by Newberry, shows 3 pairs of leaflets without a terminal leaflet; one of my specimens shows 2 associated leaflets and another 5; while none of these is attached to the associated fragments of the rachis, it is clear that they were sessile.

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[1] Chaney, Quantitative Studies of the Bridge Creek Flora, Am. Jour. Sci., vol. VIII, 143, 1924.
[2] Chaney, Am. Jour. Sci., vol. 4, 216, 1922.

Only one other species of *Odostemon* has been described from the Tertiary of North America, *O. florissantensis* Cockerell from the Florissant beds.[1] Cockerell has pointed out differences between this and the type specimen of *O. simplex*, but in view of the considerable degree of variation shown by the leaflets more recently collected, there appears to be little reason for separating these species.

Among the living barberries, *Odostemon fremontii* Rydb. is perhaps the most similar, having the sinuately 7-lobed shape which characterizes the fossil species. It has in most cases much smaller leaflets, which is in accord with its present range in the Mohave and Colorado deserts and other arid regions. A further difference is in the number of leaflets, *O. fremontii* having only 5, while the type specimen as figured by Newberry has 3 pairs of lateral leaflets, the terminal being missing. *Odostemon nervosus* Rydb. is also similar to *O. simplex*, differing in the greater number and smaller size of the marginal teeth; however, these characters appear to be rather variable in this and other living species of *Odostemon*. *O. nervosus* is a close associate of the redwood, especially in the more open parts of the forest. The absence of its leaves in the contemporary deposits of Redwood Creek has been previously noted[2] and is in accord with the paucity of the record of *Odostemon simplex* in most of the Bridge Creek fossil localities, the low representation in both cases being due to the fact that they represent forest border types, and are therefore comparatively remote from sites of deposition, and to their low habit which operates against dissemination of the leaves by wind. The fact that the leaflets of the living plant are not readily deciduous has perhaps an even more significant relation to their scarcity in sedimentary deposits. *O. nervosus* and related living species are widely distributed in the coniferous forests of the Pacific Coast and of the Rocky Mountains.

*Occurrence*—In the Crooked River Basin at the Gray Ranch, Localities 3748 and 3929; in the John Day Basin at the type locality on Bridge Creek, and at Cove Creek, being most common at Cove Creek where 16 specimens have been secured, making up over 0.2 per cent of the total of 6,689 fossil specimens counted there. Two specimens are figured from the Cove Creek locality, No. 125.

*Collection*—Univ. Calif. Coll. Pal. Bot., Plesiotypes, Nos. 82, 83, Locality 125; Plesiotype, No. 81, Locality 3748.

## Family LAURACEAE

### Genus UMBELLULARIA Nutt.

### Umbellularia oregonensis Chaney

(Plate 14, fig. 2)

*Umbellularia oregonensis* Chaney, Carnegie Inst. Wash. Pub. No. 349, pt. IV, 1925, 59-62, pl. I, figs. 1, 3, 5, 7.

This species is comparatively rare at the Crooked River localities, making up only 0.31 per cent of the total number of specimens recorded as compared with 8.82 per cent at the type locality on Bridge Creek in the John Day Basin.

The lack of any record of the fruits of *Umbellularia* has been mentioned as difficult of explanation in view of the abundance of fruits in the present-day deposits where leaves are being accumulated.[3] It is therefore of particular interest to record the occurrence of what appears to be an *Umbellularia* fruit from the deposits at the Gray Ranch. The description follows.

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[1] Cockerell, Bull. Am. Mus. Nat. Hist., vol. 24, 91.

[2] Chaney, Am. Jour. Sci., vol. 8, 135, table 3, 1924.

[3] Chaney, Am. Jour. Sci., op. cit., p. 135.

Fruit ovoid, 1.6 cm. long, with a peduncle 1.5 mm. in diameter and 1.4 cm. long which is considerably enlarged at the point of attachment.

The stout character of the peduncle makes the reference of this specimen to *Umbellularia oregonensis* probable, although more material must be secured before this determination can be considered positive. Its size is somewhat less than that of the living species, *U. californica* Nutt., due perhaps to shrinkage of the fleshy covering of the seed.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon, Localities 3748, 3749, 3750, 3927, 3929.

*Collection*—Univ. Calif. Coll. Pal. Bot., No. 75, Locality 3927.

## ORDER ROSALES

### Family SAXIFRAGACEAE

### Genus PHILADELPHUS Linné

### Philadelphus bendirei Kn., new combination

(Plate 17, figs. 1 to 5)

*Cinnamomum bendirei* Knowlton, U. S. Geol. Surv. Bull. 204, 59, pl. x, fig. 4, 1902

No less than 30 fossil species of *Cinnamomum*, about half of which are from the Tertiary, have been reported in North America, with more than a dozen additional references of a doubtful nature. In so far as these occur in floras made up largely of warm temperate or sub-tropical forms, their reference to this genus may not be open to much question even though all the living species of *Cinnamomum* are confined to eastern Asia and the East Indies at the present time. But the inclusion of members of this genus in the temperate floras of the Tertiary of America must be challenged unless the fossils show unmistakable evidence of identity with *Cinnamomum*. This is not the case for the species *Cinnamomum bendirei*, which is based on a single specimen from the type locality.

During the past six years, many additional specimens have been collected at this locality and at the Gray Ranch. As a result two differences may be pointed out between the fossils and the most closely similar living species of *Cinnamomum*, *C. camphora* T. Nees and Eberm. Of these the presence of a serrate apical margin in several of the fossil specimens is especially significant since all the leaves of *Cinnamomum* are entire-margined; the shape of the apex is also markedly different, being narrowed to a blunt tip instead of a long point as is the case with *C. camphora*.

The resemblance of the fossil specimens to *Philadelphus lewisii*, the syringa, has been previously discussed,[1] together with the ecologic evidence favoring their reference to a plant now characteristically associated with the temperate redwood forest rather than to *Cinnamomum camphora*, which is at best a warm-temperate form. The fossil species is therefore referred to *Philadelphus*, and described under a new combination as follows:

*Description*—Leaves of two types, showing the differences observable between the leaves of the sterile and fertile shoots of the living *P. lewisii*, under which designation they will here be discussed. Sterile-shoot leaves oblong-lanceolate, bluntly or, in the more slender specimens, narrowly rounded at the tip, gradually narrowing to a cuneate base; length 6.8 to 11.3 cm.; width 1.8 to 4.9 cm.; petiole stout, up to nearly 3 cm. long in the larger specimens; midrib stout, becoming more slender and in some cases slightly curved apically; a pair of strong opposite to sub-opposite secondaries branching off well above the base at an angle of about 25° and curving up toward the margin through the basal half of the leaf, branching and forming marginal loops with the more distally placed secondaries, of which there are 3 or 4 pairs, alternate or sub-opposite, and more slender than the basal pair; there may also be a very slender pair of sup-opposite secondaries leaving the midrib below the main basal pair and extending out parallel with the margin for a short distance; 3 or 4 well-defined tertiaries branch off from the lower side of the main basal secondaries and loop with one another near the margin; the other secondaries have one or two tertiary branches which form marginal loops; there are also tertiary nerves horizontally connecting the secondaries with the midrib, or branching to form a coarse rectangular network; margin entire-undulate or rarely coarsely dentate toward the apex; texture firm. Fertile-shoot leaves ovate, with a blunt apex and the base broadly cuneate or even sub-truncate; length 2.8 to 4.2 cm.; width 1.9 to 2.3 cm.; nervation as in the sterile-shoot leaves except that the main pair of secondaries branches off closer to the base of the leaf, with a well-defined basal pair branching off just below it, giving a suggestion of 5-palmate nervation; margin entire, or sparsely dentate; this type of leaf is much less numerous than those of the sterile shoots. A specimen which appears to represent a portion of the flower may be described as follows: Flower with 4 petals about 12 mm. in length, attached to a portion of the receptacle; other floral parts missing.

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[1] Chaney, Carnegie Inst. Wash. Pub. No. 349, 6-7.

Only two species of *Philadelphus* have previously been described from the Tertiary of North America, both from the Florissant beds of Colorado. Of these the leaf species, *P. palaeophilus* Cockerell,[1] is not to be distinguished from the species here described, appearing to represent the fertile-shoot type; and while it is not possible to establish a certain relationship on the basis of this single specimen, there is little doubt that the Florissant leaf is referable to *P. bendirei*. *P. macrophyllus* Cockerell[2] is a fruit species which if correctly referred to this genus, as seems probable, is doubtless of specific unity with *P. palaeophilus* as suggested by Cockerell.

*Cinnamomum spectabile* represented by a single specimen from the Miocene of Yellowstone Park[3] is closely similar to *Philadelphus bendirei*, and with the collection of additional specimens will probably be so referred; none of the other species of *Cinnamomum* from the Tertiary of North America seem to be referable to *Philadelphus*. However, there is a considerable number of species both from America and Europe, described under several generic names, which probably belong not only to that genus but in certain cases also to the species under discussion. Thus the leaf from the Bridge Creek type locality described by Newberry as *Ficus planicostata*[4] may be referable to the fertile-shoot type of *P. bendirei*, and at least the smaller leaves figured as *Ficus planicostata* by Lesquereux[5] are indistinguishable from it. The leaves referred to *Paliurus colombi* Heer by Heer from Greenland[6] and Spitzbergen[7] are indistinguishable from the fertile-shoot leaves of *Philadelphus bendirei*. Heer's *Quercus charpentieri* from the Tertiary of Switzerland[8] should properly be referred to the genus *Philadelphus* and is probably not distinguishable from *P. bendirei*. One of the leaves referred by the the writer[9] to *Populus zaddachi* Heer is clearly *P. bendirei*, as may also be the smaller leaf included in *Cercis oregonensis* Chaney.[10]

The fertile shoot leaves of *Philadelphus*, both living and fossil, have a close resemblance to those of *Ceanothus*, of which a new fossil species is described below. They can be distinguished by the presence of a second pair of basal nerves in the case of

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[1] Cockerell, Am. Mus. Nat. Hist. Bull., vol. 24, 92, pl. x, fig. 37.

[2] Cockerell, Torreya, vol. 19, 244, 1919.

[3] Knowlton, U. S. Geol. Surv. Mon. 32, pt. 2, 727, pl. xciv, fig. 6.

[4] Newberry, U. S. Geol. Surv. Mon. 35, 88, pl. xlvi, fig. 1.

[5] Lesquereux, U. S. Geol. Surv. Terr., vol. 7, 201, pl. xxxi, figs. 7, 8, 11.

[6] Heer, Fl. Foss. Arct., vol. i, 122, pl. xvii, fig. 2*d*, pl. xix, figs. 2 to 4.

[7] Heer, Fl. Foss. Arct., vol. ii, 67, pl. xiv, fig. 11.

[8] Heer, Tert. Fl. Helv., vol. ii, 56, pl. lxxviii, figs. 1 to 5.

[9] Chaney, Univ. Chicago, Walker Mus. Contr., vol. 2, No. 5, 162, pl. vii, fig. 1.

[10] Chaney, *op. cit.*, 177, pl. xvi, fig. 3.

*Philadelphus*, and in serrate-margined specimens by the comparatively large and widely-spaced teeth of *Philadelphus*.

The living *Philadelphus lewisii* Pursh., to which *P. bendirei* is closely related, is divided into two varieties, both of which are found in the Pacific Coast region. Var. *gordonianus* Lindl. is a common associate of the redwood along the coast of California, extending north into British Columbia and occurring along the valley of the John Day River in Oregon, only a few miles from the fossil localities. It shows a considerable adaptability in the amount of moisture required in this range from the moist coastal belt to comparatively dry interior, and in the latter situation doubtless constitutes a relict of the more humid forest of the Tertiary period.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3748, 3750. Specimens from Localities 3741 and 132 in the John Day Basin are also figured.

*Collection*—Univ. Calif. Coll. Pal. Bot., Plesiotype No. 104, Locality 3748; Plesiotype, No. 102, Locality 3750; Plesiotypes, Nos. 100, 101, Locality 3741; Plesiotype, No. 103, Locality 132.

## Family PLATANACEAE

### Genus PLATANUS Linné

### Platanus aspera Newberry

*Platanus aspera* Newberry, U. S. Geol. Surv., Mon. 35, 1898, 102, pl. XLII, figs. 1 to 3; pl. XLIV, fig. 5; pl. LIX, fig. 3.

Leaves of this species are found at all of the localities at the Gray Ranch, but they are in no case abundant, making up less than 1 per cent of the total of the specimens there recorded.

### Platanus condoni (Newberry) Knowlton

*Ficus* (?) *condoni* Newberry, U. S. Geol. Surv., Mon. 35, 1898, 85, pl. LVI, fig. 1; pl. LVII, fig. 1; pl. LVIII, fig. 1.

*Platanus condoni* Newb. Knowlton, U. S. Geol. Surv., Bull. 204, 1902, 64.

There is increasing evidence for the belief that the leaves referred to this species represent merely an aberrant phase of *P. aspera*. Since the Gray Ranch collections include only a single specimen, the matter of the proper status of *P. condoni* can be better considered in connection with the floras from the John Day Basin, where it is represented by numerous specimens.

## Family ROSACEAE

### Genus AMELANCHIER Med.

### Amelanchier grayi Chaney, new species

(Plate 14, figs. 3 to 5)

*Description*—Leaves ovate or obovate, with a broadly rounded apex and a broadly to narrowly cuneate base; length 3.2 to 4.2 cm., width 1.9 to 3 cm.; petiole very slender, 1.5 cm. long in the smaller specimen; midrib firm and straight; 10 or 11 pairs of secondaries, mostly sub-opposite, the lowermost pair branching off almost at the base of the leaf and extending close to its margin for about 1 cm.; secondaries slender, leaving the midrib at an angle of 55° and curving up slightly toward the margin, where they tend to fork, with the branches passing to the marginal teeth; tertiaries also branch off from the outer halves of the secondaries and end in the teeth; other tertiaries irregularly percurrent; finer nervation well preserved; base entire-margined, the rather coarse, triangular teeth being confined to the upper two-thirds of the leaf and being best developed at the apex; texture rather thin. A fruit 6 mm. in diameter seems to be referable to this species.

Of the 6 other species of *Amelanchier* recorded from the Tertiary of North America, *A. obovata* Knowlton from the Vermejo formation of Colorado,[1] *A. peritula* Cockerell,[2] and *A. scudderi* Cockerell[3] from the Florissant beds, and *A. similis* Newberry from the Fort Union of Montana[4] have a general resemblance to the species here being discussed. None of these, however, is represented by more than a single published figure, so that it has seemed desirable to describe this species as new rather than to make a correlation on inadequate evidence. More complete material, particularly from the Florissant localities, may establish its unity with one of the previously known species of *Amelanchier*. Hannibal has reported the living species, *A. alnifolia* Nutt., from the Pliocene of California.[5] In view of the similarity of the Crooked River specimens to the leaves of this living species, the persistence of a rather uniform type of leaf in *Amelanchier* may be noted throughout almost the whole of the Tertiary and up to the present.

*A. alnifolia*, the related living species, is common in western North America, from the Coast Ranges east into the Rocky Mountains and the Great Lakes region. It has a wide range of habitat, from valley bottoms, where alone it reaches the proportions of a tree, to dry mountain slopes. The comparative scarcity of its Tertiary equivalent, *A. grayi*, indicates that it was not an important constituent of the forest proper.

*Occurrence*—The Gray Ranch on the Crooked River, at Locality 3748.

*Collection*—Univ. Calif. Coll. Pal. Bot., Type, No. 76, Locality 3748; Paratypes, Nos. 77, 78, Locality 3748.

### Genus CRATAEGUS Linné

### Crataegus newberryi Cockerell

(Plate 14, figs. 6, 10)

*Crataegus flavescens* Newberry, U. S. Geol. Surv., Mon. 35, 1898, 112, pl. XLVIII, fig. 1.
*Crataegus newberryi Cockerell*, Univ. Colo. Studies, v, 1907, 43.

Leaves of this species are fairly common in most of the localities, both in the John Day and the Crooked River Basins. In view of the increased number of specimens available for study, of which the best is from the principal locality on Gray's Ranch, the following description is given.

*Description*—Leaves highly variable in shape, commonly broad-oval, in some cases obovate, rarely elongate-ovate, pinnately 5 to 11 lobed, with a blunt or rarely acute apex, and a broadly cuneate, somewhat asymmetrical base; base rarely narrow-cuneate; length 1.5 to 5.3 cm.; width 1.2 to 3.1 cm.; petiole slender, curving, up to 1.5 cm. long; midrib well defined, becoming very slender toward the apex; secondaries leaving the midrib alternately at angles of 35° to 40° and spreading out at a higher angle to end in the tips of the lobes; each giving off 4 to 6 pairs of tertiary nerves which are best developed on the basal sides of the secondaries and which end in the marginal teeth; finer nervation obscure, for the most part of percurrent nervilles; a secondary is also given off from the midrib opposite each sinus, and forks with a branch running along the border of each of the two opposite lobes; in some leaves two secondaries are given off opposite each sinus, one passing along the border of each opposite lobe; margin deeply-lobed, the sinuses reaching nearly to or rarely quite to the midrib in the basal half of the leaf, more shallow toward the apex; in the case of the small leaves all the sinuses may be shallow; sinuses mostly narrow, but broad in the case of leaves with spreading lobes; lobes broadly acute, acutely double-serrate toward their tips, especially on their basal sides; texture probably rather firm.

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[1] Knowlton, U. S. Geol. Surv., Prof. Paper 101, 269, pl. XLII, fig. 4, 1917.

[2] Cockerell, Am. Mus. Nat. Hist., Bull., vol. 24, 95, pl. VI, fig. 6, 1908.

[3] Cockerell, Bull. Torr. Bot. Club, vol. 33, 310, text-fig. 4, 1906.

[4] Newberry, U. S. Geol. Surv., Mon. 35, 111, pl. XL, fig. 6, 1898.

[5] Hannibal, Bull. Torr. Bot. Club, vol. 38, 337, 1911.

In view of the close similarity of this species to *Crataegus pinnatifida* of eastern Asia and its somewhat less marked resemblance to *C. apiifolia* of the southern United States, there can be no question as to the correctness of its reference to this genus by Newberry. As pointed out by Knowlton[1] the specimen from the Bridge Creek shales referred by Lesquereux to *Myrica diversifolia*[2] is identical with Newberry's type, and it is also indistinguishable from my specimens. Knowlton has further mentioned[3] the likeness of several of Lesquereux's specimens of *Myrica diversifolia* from the Florissant beds (figs. 7, 8, 11, 12 and 14) to Newberry's type, but has been uncertain as to their status because of the serrate character of their margins. Since all of the Bridge Creek specimens of *C. newberryi* here described have serrate margins, there is no basis for differentiating them from these figured specimens of Lesquereux's *Myrica diversifolia*.

Of the 23 fossil species of *Crataegus* described from North America, 6 are from the Cretaceous, 11 from the Tertiary, 4 from the Pleistocene, and 2 of uncertain age. Taking up the Tertiary species, there are 5 from the Denver beds, *C. antiqua*, *C. betulaefolia*. *C. engelhardti*, *C. holmesii* and *C. myricoides*, none of which resembles the species under discussion.

There are four species in addition to *C. newberryi* from the Oligocene, *C. heterodentata* and *C. pacifica* from the Eagle Creek formation of Oregon, and *C. tranquillensis* and *C. tulameensis* from British Columbia. The first of these is clearly of a different type from *C. newberryi*.[4] *C. pacifica*, which was based by the present author on inadequate material,[5] does not appear to be distinguishable from certain of the smaller specimens of *C. newberryi* in which the lobes are not deeply incised and should therefore be discarded as a distinct species. *C. tranquillensis* is unlike *C. newberryi*, and *C. tulameensis* is a fruit species. *C. imparilis* from the Mascall Miocene of Oregon[6] is also probably not to be separated from *C. newberryi*, although the presence in the single known specimen of secondary lobes has not been noted in the Bridge Creek species; however, these differences do not seem to be of specific importance in view of the great variation among the leaves of the living and fossil species of *Crataegus*, especially since only the one specimen is known to be characterized by it. The apparent identity of *C. newberryi* with certain specimens of *Myrica diversifolia* from the Florissant of Colorado has already been pointed out.

Among the living species, the leaves of *C. pinnatifida* Burge appear to have an identical range of form and size, differing only in the somewhat more acute lobes; this species occupies northern China, ranging into eastern Siberia and Korea. I have recently seen it as a common border form in the oak forest which is characteristic of the valleys and moist slopes in the hills and low mountains of Chihli and Manchuria, with annual rainfall of 23.5 to 25 inches. *C. apiifolia* Michx. of the southern United States, while not so like the fossil species as *C. pinnatifida*, has deep-lobed leaves and appears to be the most nearly related American species.

*Occurrence*—At Gray's Ranch, 11 miles east of Post, Oregon, localities 3748, 3749, 3930, 3750; also at the type locality on Bridge Creek, No. 3741, at Cove Creek, No. 125, and elsewhere in the John Day Basin.

*Collection*—Univ. Calif. Coll. Pal. Bot., Plesiotype, No. 79, Locality 3748; Plesiotype, No. 80, Locality 3741.

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[1] Knowlton, U. S. Geol. Surv. Bull. 204, 66.

[2] Lesquereux, U. S. Geol. Surv. Terr. 241, pl. L, fig. 10.

[3] Knowlton, *op. cit.*, 67.

[4] Chaney, Contr. Walker Mus., vol. 2, No. 5, 175, pl. XVI, figs. 1, 2.

[5] Chaney, *op. cit.*, 175, pl. XVII, fig. 1.

[6] Knowlton, *op. cit.*, 66, pl. X, fig. 2.

### Genus ROSA Linné

### Rosa hilliae Lesq.

(Plate 13, figs. 8 to 10; plate 14, fig. 1)

*Rosa hilliae* Lesquereux, Rept. U. S. Geol. Surv. Terr., vol. 8, 1883, 199, pl. XL, figs. 16, 17.

This species is represented by several detached leaflets and by one specimen in which the terminal leaflet, the outermost pair, and one leaflet of the pair below are attached to the rachis. They vary in shape from broadly ovate to ovate-lanceolate, the latter type probably representing the terminal leaflets. In the ovate type, which may be supposed to represent the lateral leaflets, they tend to be asymmetrical and slightly cordate at the base. The length ranges from 8 mm. to 2.1 cm., and the width from 4 mm. to 1.2 cm. The collections also include a thorny branch which appears to be Rosa and is doubtless referable to this species.

*Rosa hilliae* was described by Lesquereux from the Florissant beds of Colorado. The only other fossil species in America have also been reported from this locality—two leaf species, *R. scudderi* Knowlton[1] and *R. wilmattae* Cockerell,[2] and two fruit species, *R. ruskiniana* Cockerell[3] and *R.? inquirenda* Knowlton.[4] Knowlton[5] has pointed out that the three leaf species are much alike as to the size and shape of their leaflets, those of *R. scudderi* being somewhat more narrow than in the other two species. Leaflets of both the narrow and ovate types are found in the Gray Ranch collections, but they do not appear to show a range in shape greater than that of the closely related species, *Rosa nutkana* Presl., which is now widely distributed in western North America.

The principal means of distinguishing the three leaf species appears to have been the number of leaflets,[5] *R. hilliae* having 3, *R. wilmattae* having 5, and *R. scudderi* 7. The separation of fossil species of *Rosa* on the basis of number of leaflets seems hardly to be justified in view of the impossibility of distinguishing living species in this way. In the closely related living species *R. nutkana*, leaves with 3, 5 and 7 leaflets are commonly found on the same plant. It may further be noted that in many other living species of *Rosa*, the variation in numbers of leaflets is as great or greater. The writer is therefore inclined to believe that these three fossil leaf species, all of which are recorded from the same locality at Florissant, Colorado, are referable to a single species, and that the name *R. hilliae*, first applied to a Florissant specimen by Lesquereux, should be used for them. It seems probable that *R. ruskiniana* represents the fruit of this leaf species. The specimens from the Crooked River Basin are not distinguishable from the Florissant material.

*Occurrence*—Gray's Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3748, 3750, 3929.

*Collection*—Univ. Calif. Coll. Pal. Bot., Plesiotypes, Nos. 69, 70, 71, 74, Locality 3748.

### Genus PRUNUS B. & H.

### Prunus coveus Chaney, new species

(Plate 15, figs. 1 to 4, 6)

*Description*—Leaves broad-ovate to ovoid, rounded and apparently obtuse at the apex (tip somewhat incomplete in all specimens), slightly asymmetrical at the broadly cuneate, rarely truncate base; length 2.3 to 9 cm., width 1.7 to 4.5 cm., length of petiole about 1 cm. in the smaller specimens; midrib and petiole slightly curved, slender; 12 to 14 pairs of secondaries, slender, commonly undulating toward margin, due to slight bending at points of attachment of tertiaries, leaving the midrib at an angle of 70° near the base, decreasing to an angle of 45° at the apex, sub-parallel, camptodrome, branching well within the margin in the lower half and near the margin at the apex, commonly uniting with the branches from adjacent secondaries to form nerves which pass to the marginal teeth; tertiaries mostly irregularly percurrent; nervilles forming a distinct fine network; margin closely to sparsely serrate, the teeth obtuse with sharp tips pointing outward or apically, forming the termini of small nerves branching from the marginal loops; texture thin; the blade of the leaf on one side may be folded slightly over the midrib near the base, as is not infrequently the case in pressed specimens of modern leaves of the genus. A fruit which appears to be that of *Prunus*, and therefore referable to the leaf species, has the following characters: Fruit flattened and presumably of greater diameter as here observed than in its original state, 1.3 cm. long and nearly 1.1 cm. across; the apparently thick skin folded up into ridges in drying; seed not discernible.

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[1] Proc. U. S. Nat. Mus., vol. 51, No. 2151, 272, pl. 22, fig. 4, 1916.

[2] Bull. Am. Mus. Nat. Hist., vol. 24, 94, pl. 7, fig. 14, 1908.

[3] Am. Jour. Sci., vol. 26, 540, fig. 5, 1908.

[4] Proc. U. S. Nat. Mus., *op. cit.*, 273, pl. 17, fig. 1.

[5] Proc. U. S. Nat. Mus., *op. cit.*, 273.

Only four species of *Prunus* have been described from the Tertiary of North America, in addition to several doubtful forms. Of these, the Bridge Creek species shows its closest resemblance to *P. dakotensis* Lesquereux of the Fort Union of North Dakota[1]; the single figure of this shows the shape of the apex to be markedly acute and the margin to be rather closely serrate, with the base somewhat incomplete; if represented by more adequate material, the differences between this and *P. coveus* might be less apparent. *P. coloradensis* Knowlton from the Raton of Colorado,[2] and *P. variabilis* Newberry from the Kenai of Alaska[3] are distinct because of their more slender shape and acute apex. *P. nabortensis* Berry from the Wilcox of Louisiana[4] is represented only by a fruit. The incomplete specimens referred to *P.? merriami* Knowlton and *P.? tufacea* Knowlton from the Mascall formation of the John Day Basin[5] are described as coriaceous; additional material may indicate that they represent the same species as *P. coveus*, coming from trees which lived under less humid conditions than those of the Bridge Creek forest.

In the living flora of the West, *Prunus emarginata* Walp. has among its rather varied types of leaves many examples which are closely similar to the leaves of *P. coveus*. One of these, from sheet No. 64521 of the herbarium of the University of California, collected in the Sierra Nevada in Fresno County, California, is figured with *P. coveus* on plate 14 for comparison. The leaves of the living species vary considerably in size and texture, the larger and thinner types coming for the most part from valleys, while the small coriaceous types come from more exposed situations in regions of lower rainfall.

The size and texture of the fossil specimens are such as to indicate favorable living conditions. The discovery of so few of its leaves in the Bridge Creek shales may be taken as an indication either of the rarity of *Prunus coveus* or that it lived on the borders of the forest proper, in a situation sufficiently removed from the basins of deposition of the shales to prevent the entry of many leaves into them. The common occurrence of *Prunus emarginata* on the borders of the modern redwood forest, and its scarcity in the forest proper, suggest that the small fossil representation of *Prunus* in the Bridge Creek and other Tertiary floras of western America is due largely to such marginal distribution. The size of the fruit indicates climatic conditions favorable for its best development.

*Occurrence*—The material from the Crooked River Basin is confined to one leaf each from Localities 3751 and 3929, and a leaf and a fruit from Locality 3748. These localities are on Gray's Ranch, 11 miles east of Post, Oregon. Specimens are also figured from Localities 3931 and 125 in the John Day Basin.

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[1] Lesquereux, Rept. U. S. Geol. Surv. Terr., vol. 8, 237, pl. xlvia, fig. 8, 1883.

[2] Knowlton, U. S. Geol. Surv., Prof. Paper 101, 326, pl. xcvi, fig. 2, 1918.

[3] Newberry, U. S. Geol. Surv., Mon. 35, 112, pl. lii, figs. 3, 4 (in part), 5, 1898.

[4] Berry, U. S. Geol. Surv., Prof. Paper 91, 221, pl. cxvi, fig. 1, 1916.

[5] Knowlton, U. S. Geol. Surv., Bull. 204, 67, 68, pl. xi, figs. 2, 3, 4, 6, 7, 1902.

*Collection*—Univ. Calif. Coll.-Pal. Bot., Type, No. 89, Loc. 125; Paratypes, Nos. 85, 86, Loc. 3748; Paratype, No. 87, Loc. 3929; Paratype, No. 84, Loc. 3931.

## Family LEGUMINOSAE

### Genus CERCIS Linné

### Cercis sp.

(Plate 15, fig. 5)

Two specimens, representing portions of *Cercis* pods have been found in the Crooked River Basin, and two more, one of which is almost complete, have been secured at the type locality on Bridge Creek in the John Day Basin. As previously suggested[1] it seems probable that the leaves called *Grewia crenata* Heer are actually referable to *Cercis* and represent the same species as that of the fruits. In view of the fact, however, that the best material both of leaves and fruits comes from the John Day Basin, its further consideration will be taken up in connection with the monographing of the fossil flora of that region.

The fruit is clearly that of *Cercis;* it is listed here without description as *Cercis* sp., since its final specific name will probably depend on the relationships of the associated leaves.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3748, 3930.

*Collection*—Univ. Calif. Coll. Pal. Bot., No. 88, Locality 3748.

## ORDER SAPINDALES

## Family ANACARDIACEAE

### Genus RHUS Linné

### Rhus merrilli Chaney, new species

(Plate 16, figs. 1, 2)

*Description*—Leaflets oblong-lanceolate, rather abruptly narrowed to an acute tip, with the base rounded on one side and cuneate on the other; length 11.7 to 14 cm. (estimated), width 3.1 to 3.9 cm.; petiolule thick, 8 to 10 mm. long; midrib stout, curving regularly to the apex; 22 to 25 pairs of strong secondaries branching off at angles of 50° to 75°, the lower angles on the cuneate side, with adjacent secondaries not always parallel, in one case forking about halfway out to the margin after the manner of related living species, forking near the margin to form loops with adjacent secondaries, or curving up and connecting with a strong tertiary from the secondary above; tertiaries distinct, forming a coarse polygonal network, near the margin making well-defined loops; margin entire, distinctly undulate; texture firm.

No fossil species have been noted which are related to *R. merrilli*, the numerous species of *Rhus* from the Tertiary of North America having for the most part small and serrate leaflets. Among the living species of the United States, *R. laurina* Nutt of southern California has leaflets of similar shape, but their nervation is much more slender, and *R. vernix* L. of eastern North America has somewhat similar nervation and shape but smaller leaflets. The resemblance of the fossil species to *R. juglandifolia* Kth. var. *lindeniana* Turcz. of Mexico, and to *R. sylvestris* S. & Z. of central and southern China and Korea, is much more striking. A leaflet of *Rhus sylvestris* is figured from a specimen in the herbarium of the University of California. The tips of the leaflets of *R. sylvestris* are commonly broken or twisted, like that of the more perfect fossil specimen.

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[1] Chaney, Am. Jour. Sci., vol. VIII, 131, 1924.

The living Asiastic species, *R. sylvestris,* is most common in the Lushan Mountains of Kiangsi Province, in central China, where it may reach the size of a small tree. If the closely similar fossil species had a like habitat, on the hillsides adjacent to the site of deposition in the Crooked River Basin, the comparative scarcity of its leaves is readily understood. All of the species of *Rhus* now living in western North America are found in rather exposed situations, although certain of the eastern species, including *R. vernix* which somewhat resembles the fossil species, occupy stream and swamp borders.

*Rhus merrilli* is named in honor of Dean Elmer D. Merrill of the University of California, who first suggested the reference of the fossil material to this genus.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3748, 3930. It is found also on Cove Creek in the John Day Basin, at Locality 127, from which a specimen has been figured.

*Collection*—Univ. Calif. Coll. Pal. Bot., Type, No. 94, Locality 3748; Paratype, No. 93, Locality 127.

### Rhus praeovata Chaney, new species

(Plate 15, figs. 8, 9)

*Description*—Leaves ovate gradually narrowing to a rather blunt apex, broadly cuneate at the base; length 3.6 to 4.7 cm., width 2.7 cm.; petiole heavy, slightly twisted, 6 mm. long; midrib stout, curving slightly toward the apex; 6 or 7 pairs of well-defined secondaries, the basal pair branching off at or slightly above the base and giving a suggestion of a 3-nerved or 3-plinerved leaf; secondaries leaving the midrib at an angle of 40°, and forking once or twice in the outer third of the leaf, where they form loops with the tertiaries well within the margin; 8 or more tertiaries branch adaxially from the basal secondaries and form marginal loops; other tertiaries form a coarse network, including small branches from the midrib between the secondaries; margin slightly undulate, entire or sparsely denticulate with small branches from the marginal loops ending in the teeth; texture firm.

None of the fossil species of *Rhus* from North America appears to be related to this species, whose close resemblance to the living *R. ovata* Wats. is indicated by its name. *R. ovata* occupies dry hills in southern California and is characterized by much thicker leaves than *R. praeovata* seems to have had. This may be taken as an indication that the latter lived under somewhat more mesophytic conditions, which is consistent with other data on the climatic conditions during the Bridge Creek epoch. Its probable distribution on the open slopes of the forest border accounts for the comparative scarcity of the leaves of *R. praeovata.*

A specimen of *R. ovata* from the herbarium of the University of California, sheet 168786, is figured for comparison.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Locality 3748.

*Collection*—Univ. Calif. Coll. Pal. Bot., Type, No. 91, Locality 3748; Paratype, No. 90, Locality 3748.

## Family ACERACEAE

### Genus ACER Linné

### Acer osmonti Knowlton

(Plate 17, fig. 6; plate 18, figs. 1, 3, 5, 7–9)

*Acer osmonti* Knowlton, U. S. Geol. Surv. Bull. 204, 1902, 72, pl. XIII, fig. 3.

This species is based on a single nearly complete specimen from the Bridge Creek locality in the John Day Basin, and until recently no other leaves of *Acer* have been known from the Bridge Creek flora. Several incomplete though typical specimens of

*A. osmonti* have been secured by the writer in the Crooked River Basin, and in addition a number of 3-nerved maple leaves have been collected here and in the John Day Basin. These latter have been described in manuscript as a distinct species, closely related to the living *A. glabrum* Torr. But in the course of a comparison of the fossil specimens with their living relative, the extent of variation in the leaves of *A. glabrum* has been observed to include not only the more abundant 3-nerved type, but also the 5-nerved type of leaf which is like *A. osmonti.* The fact that the 3-nerved type is the more common in the case of the fossil leaves as well, and that both leaf types are represented in the range of variation of this living species, makes it seem probable that only one fossil species is involved. This conclusion is strengthened by the fact that the fossil fruits of *Acer*, which in most localities are more numerous than the leaves, are all of one type.

The type specimen of *A. osmonti* is not to be found in the palaeontological collections of the University of California, but judging from the figure[1] in which the basal features are somewhat obscure, it is not certainly primarily 5-nerved, but appears rather to have the basal pair of nerves, which terminate in the basal lobes, branching off from slightly above the bases of the lateral primaries; in other words the basal pair of nerves seem to be secondaries rather than primaries. Two 3-lobed maple leaves were figured by Knowlton from material collected at Clarnos Ferry in the John Day Basin, but were not given a specific name because of the fragmentary condition of the specimens.[2] In view of the fact that additional material, part of which is somewhat unlike the type specimen, is here being referred to *A. osmonti*, the following description is given.

*Description*—Leaves highly variable in shape, primarily 3-lobed, possibly primarily 5-lobed, but in the case of all the 5-lobed leaves studied the basal pair of lobes is comparatively small, and the nerves terminating in them appear to have the relation of secondaries rather than primaries; lobes varying in shape from short and broad with open sinuses in the case of the 3-lobed leaves, to long and slender with narrow sinuses in the case of the 5-lobed leaves; in the larger leaves the central lobe may have a pair of small lateral lobes; base truncate or cordate, less commonly broadly cuneate; length 3.5 to 8 cm., width 3.8 to 9.4 cm., average dimensions 6.8 by 7.2 cm.; petiole rather stout, reaching a length of over 5 cm. in the larger specimens; central primary and lateral pair of primaries stout, branching from the top of the petiole and terminating in the principal lobes; in a number of specimens secondary branches are given off near the base of the lateral primaries which terminate in a pair of basal lobes; these secondaries are more slender than the outer primaries and are clearly subordinate to them, although in certain specimens they appear to branch off very close to the base of the leaves; in all, 5 to 8 secondaries branch off from the adaxial side of the lateral primaries, terminating in the marginal teeth; in the case of leaves whose lateral lobes are separated by deep sinuses from the central lobe, an equal number of secondaries branch off from the axial side of the lateral primaries and terminate in the margin; secondaries from the central primary sub-opposite; the lowermost may pass out to the sinuses between the central and lateral lobes; the remainder terminate in the marginal teeth, or in the case of certain larger specimens one of the lower pairs may end in small lobes; tertiaries and nervilles forming a fine and irregular network; margin set with numerous small, rather obtuse but sharply pointed teeth, which are larger where they are the termini of the secondary nerves; texture rather thin. Fruit more numerous than leaves; seeds, oval, rarely globose, up to 8 mm. in length and 5 mm. in width, commonly slightly flattened on the end of attachment; samara up to 4.2 cm. long, strongly nerved along the upper, comparatively straight side, obovate, deeply constricted below the seed and widening to nearly 1.5 cm. with distinct bifurcating nerves. The fruits are always found singly, but the beveling at their point of attachment is such as to indicate that they hung down in pairs, almost along the axis of the peduncle.

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[1] Knowlton, U. S. Geol. Surv., Bull. 204, pl. XIII, fig. 3, 1902.

[2] Knowlton, *op. cit.*, 72, pl. XIII, figs. 1, 2.

As indicated above, this fossil species shows the closest relation among the living species of American maples to *A. glabrum*, a species common in the west; certain of the fossil specimens also resemble the leaves of *A. spicatum* Lam., an eastern species. The leaves of *A. glabrum* are highly variable, commonly 3-nerved and 3-lobed, but in some cases 5-nerved and 5-lobed; where 5-lobed the basal lobes are small as in *A. osmonti*. The sinuses between the central and lateral lobes vary from broad to narrow, in some cases dividing the leaf into 3 leaflets, a form not represented in *A. osmonti*. The seeds have the same range of size and shape, and the same position of attachment as in *A. osmonti*. *Acer glabrum*, the dwarf maple, ranges from southeastern Alaska down the coast to British Columbia, southward in the mountains to the San Bernardino Range in southern California and eastward into the Rocky Mountains. Its nearest observed occurrence to the Crooked River Basin is in the Blue Mountains of Oregon, less than 50 miles distant from the fossil locality; doubtless it might be found within a few miles of Gray's Ranch in the nearby mountains. Its most common habitat is on rocky canyon sides and most slopes, at 6,000 to 8,000 feet in the Sierra Nevada and down to sea-level in the northern part of its range. The similar species of the eastern United States, *A. spicatum*, has much the same habitat, but occurs at lower elevations.

No American fossil species of *Acer* appear to be closely related to *A. osmonti*.

Several leaves of *A. glabrum* from specimens in the herbarium of the University of California are figured with the fossil specimens to indicate their close resemblance to the fossil species.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3748, 3749, 3750, 3751, 3927, 3930. Fruits are more common than leaves, which is also the case in the John Day Basin collections, from which leaves and seeds are here figured.

*Collection*—Univ. Calif. Coll. Pal. Bot., Plesiotypes, Nos. 105, 108; Plesiotype, No. 106, Locality 3927; Plesiotype, No. 109, Locality 3750; Pelsiotype, No. 111, Locality 3741; Plesiotypes, Nos. 107, 110, Loc. 125.

## ORDER RHAMNALES

### Family RHAMNACEAE

### Genus CEANOTHUS Linné

### Ceanothus blakei Chaney, new species

(Plate 16, figs. 4, 6 to 9)

*Description*—Leaves ovate or oblong-ovate, strongly 3-nerved, gradually narrowing to a rounded or bluntly pointed apex, with a slightly cordate base, beyond which the midrib and the pair of basal secondaries may project for a short distance; length 2.1 to 6 cm., width 1.5 to 2.9 cm.; petiole stout, up to 1.3 cm. long; midrib strong, slightly curving, with a pair of stout secondaries branching off at the base or little below the blade of the leaf, curving up parallel to the midrib and terminating in the apical region; several pairs of sub-opposite secondaries leave the midrib in the upper part of the leaf, curving parallel with the margin; from the abaxial sides of the basal secondaries 8 or more stout tertiary branches are given off, which curve and form loops near the margin; from the axial sides of the basal secondaries, tertiaries run across to the midrib, with cross-branches which form a fine network; tertiaries in the apical region mostly percurrent; margin glandular-serrate or serrulate; texture rather thin.

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Of the four species of *Ceanothus* which have been recorded from the Cretaceous of North America, *C. cretaceous* Dawson[1] and *C. ovatifolius* Knowlton[2] are 3-nerved but of a different shape from *C. blakei* and with entire margins; *C. eriensis* Knowlton[3] has the same general shape as C. *blakei* and a serrate margin, but its nervation is much less distinctly 3-nerved and it is distinguished by other details of the nervation; *C. constrictus* Hollick[4] is a wholly different type of leaf from *C. blakei; Ceanothus?* sp. Dawson[5] from the Oligocene of British Columbia is somewhat like the species under discussion, but has a more slender shape and an entire margin. The living species, *C. americanus* L. has been doubtfully reported from the Pleistocene of Kentucky.[6]

The writer is inclined to believe that some of the Tertiary leaves referred to two other genera of the Rhamnaceae, *Paliurus* and *Zizyphus*, may better be placed in *Ceanothus*.[7] From the standpoint of their present distribution, neither of these genera might be expected to occur in a temperate flora in western America, since both are largely tropical and have their centers of distribution in Asia and Indomalaysia. On the other hand, *Ceanothus* is confined to temperate North America and has its greatest development on the Pacific Coast and in other parts of the West. It is equally significant to note that certain of the leaves figured as *Paliurus* and *Zizyphus* do not resemble the leaves of living representatives of these genera as closely as they do those of *Ceanothus*. A typical example is *Paliurus colombi* Heer, which as figured by Lesquereux[8] lacks the closely serrate margin characteristic of the living species of this genus, but is hardly distinguishable from several species of *Ceanothus* now living upon the Pacific Coast. It is significant to note that Lesquereux himself recognized this relationship, stating[9] that "by the shape of the leaves and the nervation, this species is allied to *Ceanothus thyrsiflorus* Esch. of California." The resemblance of his figured specimens to *Ceanothus integerrimus* H. & A. is even more apparent, since the leaves of this living species commonly have entire margins or may have sparse teeth like those of Lesquereux's figures 14 and 17. The leaves figured as *Zizyphus meekii* Lesq.[10] and *Z. paliurifolius* Knowlton[11] appear to have more the shape, nervation and margin characters of *Ceanothus*. The figured specimen of *Cinnamomum scheuchzeri* Heer from the Florissant beds[12] is strikingly similar to those of the living *Ceanothus thyrsiflorus*, as are the leaves of *Cinnamomum dilleri* Knowlton[13] from Oregon. There can be little question as to reference of *Ficus mensae* Cockerell, as figured by Lesquereux[14] and as represented by specimens recently collected by the writer at Table Mountain, California, to a species of *Ceanothus* of the *integerrimus* type. It is even possible that certain of the leaves figured as *Populus arctica* Heer[15] (notably figures 4, 7 and 8) may ultimately be recognized as those of *Ceanothus*.

Among the leaves of the living species of *Ceanothus*, *C. blakei* bears its closest resemblance to *C. sanguineus* Pursh (also known as *C. americanus* L.), which is the most widespread member of the genus ranging across the whole of the United States. Discussing the position of *C. blakei* in the genus, McMinn has stated[16] that it should be referred to the sub-genus *Euceanothus*, including species with leaves of the more primitive 3-nerved type which appear to have been derived from *Paliurus* or *Zizyphus*. *C. sanguineus* ranges from northern California north into British Columbia and eastward into Idaho, being associated with coniferous forests. The fossil leaves are also similar to certain of the leaves of *C. thyrsiflorus* (see sheet No. 58242 in the herbarium of the University of California), which is especially abundant in the Redwood Belt of Western California; a leaf of this living species is figured for comparison.

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[1] Dawson, Roy. Soc. Canada, Trans., vol. 1, sec. 4, 28, pl. viii, fig. 33, 1882.

[2] Knowlton, U. S. Geol. Surv., Prof. Paper 130, 153, pl. xxv, fig. 3, 1922.

[3] *Op. cit.*, 152, pl. xxvi, figs. 3 to 6.

[4] Hollick, U. S. Geol. Surv., Mon. 50, 93, pl. xxiv, figs. 15 to 17, 1906.

[5] Dawson, Roy. Soc. Canada, Trans., vol. 8, sec. 4, 84, text-fig. 14, 1890.

[6] Lesquereux, Am. Jour. Sci., 2d ser., vol. 27, 365, 1859.

[7] Twenty fossil species of *Paliurus* have been described from North America, and 27 species of *Zizyphus*.

[8] Lesquereux, Rept. U. S. Geol. Surv. Terr., vol. 7, 273, pl. l, figs. 13 to 17, 1878.

[9] *Op. cit.*, 273.

[10] Lesquereux, Rept. U. S. Geol. Surv. Terr., vol. 7, 275, pl. li, figs. 10 to 14, 1878.

[11] Knowlton, U. S. Geol. Surv., Prof. Paper 101, 272, pl. xlvii, figs. 1 to 4, 1918.

[12] Lesquereux, Rept. U. S. Geol. Surv. Terr., vol. 8, 165, pl. xxxviii, fig. 6, 1883.

[13] Knowlton, U. S. Geol. Surv., 20th Ann. Rept., pt. 3, 47, pl. iv, fig. 1, 1900.

[14] Lesquereux, Mus. Comp. Zool., Mem., vol. 6, No. 2, 18, pl. iv, figs. 10, 11, 1878.

[15] Lesquereux, Rept. U. S. Geol. Surv. Terr., vol. 8, 225, pl. xlvi, figs. 2 to 13, 1883.

[16] Oral communication of Sept. 3, 1926. H. E. McMinn and H. M. Hall are making a monographic study of the living members of the genus *Ceanothus*.

*Ceanothus blakei* is named in honor of Mr. and Mrs. Anson S. Blake, in whose gardens many interesting plants are available for study, including several living species of *Ceanothus* which first suggested the relationships of the fossil material.

*Occurrence*—Gray's Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3748, 3927, 3929, and 3930. Leaves occur also at the type locality on Bridge Creek, in the John Day Basin and one of them is here figured.

*Collection*—Univ. Calif. Coll. Pal. Bot., Type, No. 95, Loc. 3929; Paratypes, Nos. 96, 97, Locality 3748; Paratype, No. 98, Locality 3930; Paratype, No. 99, Locality 3741.

## ODER MALVALES

### Family TILIACEAE

### Genus TILIA Linné

### Tilia sp.

One specimen of a pedunculate bract of *Tilia* has been found at Locality 3748. While there is no question as to its reference to this genus, it has seemed desirable not to name and describe a new species of *Tilia* at this time, since there are numerous specimens both of leaves and fruits in the Bridge Creek collections from the John Day Basin. This material, which bears a relation to several living species of the genus, will be described in a later paper on the floras of the John Day Basin.

The Gray Ranch specimen is much more slender than the pedunculate bracts described as *T. pedunculata* Chaney, from the Eagle Creek formation, but it can not be definitely stated at this time that they are distinct.

## ORDER MYRTIFLORAE

### Family NYSSACEAE

### Genus NYSSA Linné

### Nyssa crenata Chaney

(Plate 15, fig. 11)

*Nyssa crenata* Chaney, Univ. Chicago. Walker Mus. Contr., vol. 2, No. 5, 1920, 180, pl. xx, figs. 1, 2.

A single fragmentary specimen has been found at Locality 3748 which is probably referable to the Eagle Creek species. It has the same size, shape and nervation, and the margin is similar except that it bears a few small teeth. In view of the relatively coarse matrix in which the Eagle Creek specimens occur, it is probable that teeth of this type would not have been preserved on them.

## ORDER UMBELLIFLORAE

### Family CORNACEAE

### Genus CORNUS Linné

**Cornus ovalis Lesquereux**

(Plate 19, figs. 1 to 4)

*Cornus ovalis* Lesquereux, Mem. Mus. Comp. Zool., vol. 6, No. 2, 1878, 23, pl. VI, figs. 1, 2.

Leaves of *Cornus* are of infrequent occurrence at any of the localities of the Bridge Creek flora. Extensive collections at the type locality on Bridge Creek have within the last few years yielded some 10 leaf specimens which seem referable to Lesquereux's species from the Auriferous Gravels at Tuolumne Table Mountain, California. Two of these are figured, together with a set of involucral scales which appear to be those of *Cornus*. Similar material from the Mascall formation has been described as *Hydrangea bendirei* Knowlton, but it seems more properly referable to *Cornus*.

Only two leaf specimens have been collected at the Gray Ranch localities, both incomplete, but with the characteristic nervation which makes their reference to *Cornus* certain; their size and general appearance is similar to that of *C. ovalis*.

*Occurrence*—Gray's Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3748 and 3750.

*Collection*—Univ. Calif. Coll. Pal. Bot., Plesiotype, No. 114, Locality 3750; Plesiotypes, Nos. 112, 113, 115, Locality 3741.

## ORDER ERICALES

### Family ERICACEAE

### Genus ARBUTUS Linné[1]

**Arbutus matthesii Chaney, new species**

(Plate 20, figs. 1, 3 to 5)

*Quercus elaenoides* Lesquereux, Mus. Comp. Zool., Mem., vol. 6, No. 2, 1878, 4, pl. I, fig. 9 only.

There has been no fossil record of this genus in America except for the specimen of the living species, *Arbutus menziesii* Pursh., figured by Hannibal from the Pliocene of California.[1] In view of its imperfect preservation there may be some question as to the reference of that specimen to the living species, though its place in the genus seems justified.

For several years past, the writer has been collecting specimens at various localities and horizons which also are referable to the genus *Arbutus*. All of these appear to be of a single type, readily distinguishable from the living species by their shape, but with the characteristic nervation and texture of the madroño. One of these specimens has recently been found in the Bridge Creek shales at the Gray Ranch, and the species will be described in this flora because of its interesting relations to the other members of the Bridge Creek forest. Most of the material on which this new species is based, however, comes from other Tertiary localities in the West.

*Description*—Leaves varying from broadly ovate to oval or obovate, with the apex acute, or rounded and contracted into a short, sharp point, and the base narrowly to broadly cuneate; length 6 to 8 cm., width 2.13 to 4.7 cm., average dimensions 4 by 6.9 cm.; petiole very stout, up to 1.8 cm. long, midrib heavy, much reduced toward the apex; secondaries numerous in most specimens, up to 20 pairs, slender, curving irregularly and forking to form loops well within the margin; secondaries less conspicuous on the lower surface of the leaf (see figs. 4, 5, pl. 20) tertiaries well developed, branching off rather irregularly from the outer ends of the secondaries to form marginal loops; nervilles obscure; margin revolute, entire or sharply serrate; texture coriaceous, with an undulate margin.

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[1] Bull. Torr. Bot. Club, vol. 38, 339, pl. XV, fig. 1, 1911.

From an examination of the types of *Quercus elaenoides* it is clear that at least one of the specimens figured by Lesquereux, as above indicated, is actually referable to *Arbutus matthesii;* three of the specimens here figured, including the type, come from the same general locality as this specimen of Lesquereux-Tuolumne Table Mountain, California.

*Arbutus matthesii* bears a strong resemblance to the common living representative of its genus in western America, *A. menziesii*, of which a leaf is figured on plate 20 for comparison. The fossil leaves average much smaller than those of the living species, and they show a greater tendency toward obovateness in shape. The present distribution of *A. menziesii* on the borders of the redwood forest is of particular interest in connection with the occurrence of a fossil equivalent in the flora at Gray's Ranch. This contains a conspicuous group of border species associated with the typical redwood species, differing in this respect from the Bridge Creek flora of the John Day Basin in which most of the species and specimens are typical forest types. It is in just such a border habitat that the finding of a fossil species of *Arbutus* would be expected; even here only a single specimen has been recorded, indicating that the Tertiary madroño was by no means common on the margins of the basins of deposition.

This species is named in honor of Dr. F. C. Matthes, who collected the first specimens from the Table Mountain locality in California.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon, Locality 3748; also at the Buchanan Tunnel, Table Mountain, 1.5 miles east of Columbia, California; Locality 92.

*Collection*—Univ. Calif. Coll. Pal. Bot., Type, No. 119, Locality 92; Paratypes, Nos. 120–121, Locality 92; Paratype, No. 122, Locality 3748.

## ORDER GENTIANALES

### Family OLEACEAE

### Genus FRAXINUS Linné

### Fraxinus denticulata Heer

(Plate 19, figs. 5 to 7)

*Fraxinus denticulata* Heer, Fl. Foss. Arct., vol. 7, pt. 2, 1883, 112, pl. LXXX, figs. 4 to 7 (not 8). Newberry, U. S. Geol. Surv., Mon. 35, 1898, 128, pl. XLIX, fig. 6.

This species, previously represented in the Bridge Creek deposits by only a single leaflet, has been recently collected to the number of about 30 specimens. The occurrence is commonly in the form of dissociated leaflets although in one specimen there are 3 leaflets together on the slab in such a position as to indicate that they represent the terminal leaflet and the upper pair of laterals of the same leaf. Since the bulk of the material comes from the type locality on Bridge Creek in the John Day Basin, the full discussion of this species will be reserved for the paper on the John Day floras.

Among living species, *F. denticulata* is most closely related to *F. oregona* Nutt., which ranges from British Columbia southward into California. The Oregon ash is most common and at its best in the vicinity of streams, especially in the northern portion of its range where climatic conditions are more favorable. Its association with the redwood on the Eel River and elsewhere in the Redwood Belt is significant, since it is characteristically found on the borders of the forest and along open stretches of the streams. The comparatively small number of leaflets of *F. denticulata* in the Bridge Creek shales is doubtless due to the fact that this species, like its living counterpart, had a distribution marginal to the forest proper. The absence of seeds from the record is somewhat difficult to explain, but tends to emphasize the suggestion that *F. denticulata* was not commonly present near the basins of deposition.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3748, 3750, 3930, 135. Leaves from Locality 3741 in the John Day Basin are also figured here.

*Collection*—Univ. Calif. Coll. Pal. Bot., Plesiotype, No. 118, Locality 3748; Plesiotypes, Nos. 116, 117, Locality 3741.

## PLANTS OF UNCERTAIN SYSTEMATIC POSITION

The following three species are discussed separately, due to the fact that there is no present basis for determining their taxonomic position.

### Cyperacites sp.

The material of this form is too incomplete to indicate more than a general relationship to grass-like plants. Due to the fact that their leaves are not definitely shed but commonly wither while still attached to the plants, grasses and sedges are not commonly represented in the sediments along stream courses in the Redwood Belt, even though they are rather commonly present there. Much the same inhibiting factor may be supposed to account for their rare occurrence in most of the Tertiary floras of western America.

The specimens from the Bridge Creek flora of the Crooked River Basin, of which only two or three have been found, have the same general appearance as the material described as *C. angustifolia* Chaney,[1] from the Eagle Creek formation where they are more numerous. Both may be related to *Torresia macrophylla* (Thurb.) Hitchc., a common living grass of the Redwood Belt, but such a relationship can only be suggested in view of the fragmentary nature of the fossil specimens.

*Occurrence*—The Gray Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 135 and 3751.

### Grewia crenata (Unger) Heer

*Grewia crenata* Heer, Fl. tert. Helv., vol. 3, 1859, 42, pl. cix, figs. 12 to 21; cx, figs. 1 to 11.

A more complete discussion of this species will be reserved for a later paper on the John Day floras, in which it is much more abundantly represented. For the present it need only be said that while the Gray Ranch specimens are indistinguishable from those of this species from other parts of western North America and of Europe, the reference of any of them to the genus *Grewia* seems wholly without justification. When a fossil species of a genus at present confined to tropical portions of the southern hemisphere is included in a typically north-temperate assemblage such as the Bridge Creek flora, it is more than ever necessary to determine that there is an unquestioned resemblance between it and living species of the genus, and that there is no temperate genus to which the resemblance of the fossil is not as close. In the case of *Grewia crenata*, its resemblance to living species of *Grewia* is no more marked than its similarity to living species of the genus *Cercis* and the genus *Cercidiphyllum;* the former is a typical member of the north-temperate flora of western America, and the presence of *Cercis* pods appears to establish its presence in the Bridge Creek flora; the latter occurs in temperate Japan and China and the leaves of one of the species, *C. japonicum*, var. *sinense* Rehd. and Wils., appear to be almost identical with the fossil leaves of *Grewia crenata*. It seems probable that upon a final review of the evidence furnished by the extensive collections from the John Day Basin, the writer will refer these leaves either to *Cercis* or *Cercidiphyllum*.

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[1] Chaney, Walker Mus. Contr., vol. ii, No. 5, 160, pl. vi, fig. 2, 1920.

*Occurrence*—Gray's Ranch, Crooked River Basin, 11 miles east of Post, Oregon; Localities 3748, 3750, 3751, 135.

### **Porana speirii Lesquereux**

*Porana speirii* Lesquereux, Rept. U. S. Geol. Surv. Terr., vol. 8, 1883, 172, pl. XXVIII, fig. 15.

A single specimen from Locality 3749 on Gray's Ranch is referable to this Florissant species, as are a large number of specimens from Locality 125 and elsewhere in the John Day Basin.

While it must be admitted that this and the three other species referred to *Porana* from the Florissant beds have some resemblance to the flowers of this Convolvulaceous genus, its presence in a typically temperate flora like the Florissant is open to serious question. To be sure a considerable number of other species in the Florissant flora are included which represent genera largely tropical in their present day distribution, but the writer ventures the prediction that few if any of these will withstand critical scrutiny. Further doubt as to the correctness of this generic reference is caused by the statement of Dr. E. D. Merrill[1] that the living species in Indomalaysia occur as sprawling shrubs in thickets and on open slopes, but never in forests or in situations where their flowers would be likely to enter sedimentary deposits. Pending the discovery of a suitable genus in which to place these fossil remains the name *Porana* is used, since by it the geologic relationships can be indicated.

## THE BRINK RANCH FLORA

### GEOGRAPHIC AND STRATIGRAPHIC OCCURRENCE

On the ranch of Judge M. E. Brink, 3 miles east of Prineville, the basalt which forms a conspicuous cap on the buttes in this vicinity is underlain by 200 feet or more of volcanic sediments. These are light yellowish in color and are unconsolidated for the most part, but in the upper portion there are several layers of compact ash and tuff, in which leaf impressions and silicified wood occur. The section is as follows:

| | *Feet* |
|---|---|
| Basalt flows and talus | 75 (to top) |
| Unconsolidated sandy tuff with thin layers of ash, some agglomerate near top | 60 |
| Coarse white ashy shale, no fossils noted | 1 |
| Unconsolidated ashy tuff | 50 |
| White ashy shale, with leaves and small stumps in position. Locality 3947A | 2 |
| Unconsolidated ashy tuff | 20 |
| Thinly bedded white ashy shale underlain by several inches of lignitic shale. Fossil fragments | 3 |
| Unconsolidated ashy tuff | 20 |
| White ashy shale and sandstone, with leaves and a large stump. Locality 3947 | 2.5 |
| Unconsolidated ashy tuff | 60 (to base of slope) |
| | 293½ |

The sediments and the lava dip 4° toward the west, the former outcropping for a distance of about 2,000 feet along the side of the butte. To the north and east at a distance of a mile or more from the Combs Flat road, sediments with a similar appearance have been noted below the lava.

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[1] Personal communication of Sept. 21, 1926.

## COMPOSITION OF THE FLORA

The leaf impressions are well defined, but due to a high degree of jointing and weathering it has been impossible to collect many complete specimens and some of the specific references are therefore doubtful. Although they do not differ greatly in content, the collections from the two principal horizons are listed separately.

### LOCALITY 3947

Leaves occur in a 2.5-foot layer of consolidated ash and tuff, about 60 feet above the base of the slope. At the same level is a *Sequoia* stump 52 inches in diameter and apparently in position. Due to the harder character of the leaf zone, it forms a well-defined band across the face of the exposure. The following species have been recognized:

Alnus sp (cone)
Cornus ovalis
Platanus condoni(?)
Quercus cowlesi
Quercus pseudolyrata(?)
Sequoia langsdorfii

### LOCALITY 3947A

Leaves also occur in an ash layer about 40 feet above No. 3947, in association with several small silicified stumps. The following species have been noted:

Platanus condoni(?)
Quercus cowlesi
Quercus pseudolyrata(?)
Sequoia langsdorfii

While most of these species occur in the Bridge Creek shales of the Lower John Day Series both on the Gray Ranch and in the John Day Basin, the broad-leafed oaks, *Q. cowlesi* and *Q. pseudolyrata*(?), make up an element which is not present in the Bridge Creek flora. This element is of importance both from the standpoint of the physical conditions indicated and the age of the sediments at Brink's Ranch.

*Sequoia langsdorfii* is the most abundant species at both horizons, and the leaves of *Quercus cowlesi* are also numerous. None of the other species are represented by more than one or two specimens. The alder cone, while not showing definite specific characters may be supposed to represent the fruit of *Alnus carpinoides* of the Bridge Creek shales or of *A. oregoniana* of the Eagle Creek formation. The specimens doubtfully referred to *Platanus condoni* and *Quercus pseudolyrata* are too incomplete to justify positive determinations. In the case of the latter species, however, it is clearly a broad-leafed oak and of a different type than *Q. cowlesi*.

Since none of the species represented in the Brink Ranch collections are new, and since the material in no way adds to our knowledge of their characters, there will be no occasion to discuss them individually.

## PHYSICAL INDICATIONS

The occurrence of leaves and wood of *Sequoia langsdorfii* together with the cone of an alder indicates that a forest resembling that of the Bridge Creek epoch was present in the vicinity of Prineville during the accumulation of the sediments at the Brink Ranch. While the size of the fossil flora is not sufficient to permit any final conclusions as to the climatic and topographic conditions extant at this time, the broad-leafed oak element furnishes highly significant suggestions. This element has never been found in the Bridge Creek flora of Western North America or in corresponding floras of other continents, and it may be assumed not to have been a part of the typical Oligocene redwood forest. Further, the living broad-leafed oaks of California are not found in direct association with the redwood, although they grow on the borders of the forest, especially in the southern and drier portion of the Redwood Belt.

Broad-leafed oaks are, however, abundantly represented in the Mascall flora at several localities in Washington, Oregon and Nevada, including the type locality near Dayville in the John Day Basin. Here they make up over 11 per cent of the total, a percentage which is probably exceeded in the Latah formation at Spokane where no quantitative data are now available. In the Eagle Creek formation of the Columbia River Gorge, broad-leafed oaks make up more than 36 per cent of the total. Both these formations are younger than the Lower division of the John Day Series, the Mascall being referred to the Middle Miocene and the Eagle Creek being probably the equivalent of the Upper division of the John Day Series. The Mascall flora contains a redwood element, but the assemblage as a whole is of a distinctly less humid type than the Bridge Creek flora, indicating a reduction in rainfall from 40 inches in the Bridge Creek epoch to 30 inches in the Mascall epoch. The evidence for this climatic change has been elsewhere discussed by the writer,[1] and not the least important proof of the diminution in rainfall is the abundance of the broad-leafed oaks. The Eagle Creek flora also represents a drier type of forest than the Bridge Creek, with an entire absence of *Sequoia*.

The Brink Ranch flora, as previously mentioned, has two species of broad-leafed oaks, one of which, *Q. cowlesi*, is more common than any other species except *Sequoia langsdorfii*, and the other, doubtfully referred to *Q. pseudolyrata*, is also wholly unlike the typical oaks of the Bridge Creek flora, *Q. consimilis* and *Q. clarnensis*. The broad-leafed fossil species are identical with or similar to the common oaks of the Eagle Creek and Mascall floras, both of which are younger than the Bridge Creek and which appear to represent forests which lived under conditions of less rainfall than are necessary to support a typical redwood assemblage. There is some evidence also for the assumption that the conditions incidental to the deposition of the Mascall and Eagle Creek formations involved a more open type of topography than that of the Bridge Creek shales, in which the sediments are more uniformly fine and the fossil species more distinctly of closed valley types. The Brink Ranch flora may therefore be considered to represent a forest living in a region of rather broad open valleys, and with the annual rainfall probably nearer 30 than 40 inches. The occurrence of the leaves in well-defined layers of ash indicates that the leaf-bearing deposits represent the accumulation of showers of pyroclastic material in lake or valley basins.

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[1] Carnegie Inst. Wash. Pub. No. 349, No. 2, 46, 1925.

In consideration of the physical conditions under which the Bridge Creek shales were deposited, three causes have been suggested, on page 92, for the paucity of plant fossils in the John Day Series above its Lower division. The first of these does not necessitate any reduction in the amount of forested area, but suggests that the limited plant record is due to the infrequency of volcanic eruptions which dropped fine ash and that the opportunities for the preservation of leaves and fruits were therefore lessened. The second and third causes have to do with a reduction in the forested area, due to the wearing down of the divides and the consequent opening up of the valleys which the forest occupied, and to a diminished rainfall which made conditions unfavorable for trees. Either of these causes would have resulted in an increase of grasslands at the expense of the forests. The faunal evidence of the Middle and Upper divisions of the John Day Series indicates that there were many plains types of mammals, and that their remains were mingled with those of forest-inhabiting types. It may be supposed that all three of these causes were involved in the diminution of the floral record, and that not only did conditions become unfavorable for the preservation of plants, but that the forest itself was gradually restricted and altered, due to topographic changes and to reductions in rainfall. The close of the John Day epoch in eastern Oregon shows the redwood forest modified by the entrance of broad-leafed oaks, and apparently reduced in area by the advance of grasslands in which lived a varied plains fauna, and in which conditions for the preservation of plants in the record were not favorable.

## CORRELATION

From the preceding discussion it is clear that the Brink Ranch flora is more closely related to those of the Eagle Creek and Mascall formations than to the Bridge Creek flora. The incoming of the broad-leafed oak element is a critical feature, indicating as it does a reduction in rainfall, and in view of its presence the age of the Brink Ranch flora may definitely be placed as younger than the Bridge Creek.

The discovery by Charles Merriam of hypertraguline remains in the exposures adjacent to the leaf shales at Brink's Ranch has an important bearing upon the problem of their age. Similar vertebrate material has been recorded from the Middle and Upper divisions of the John Day Series in the John Day Basin and at Logan Butte in the Crooked River Basin. The faunal evidence is therefore in accord with that of the flora in indicating that it is younger than the Bridge Creek flora of the Lower division.

The stratigraphic evidence is in harmony with the conclusions based upon the fossils. The Brink Ranch sediments are overlain by flows of olivine basalt which are not only similar in composition and general appearance to the Columbia Lava of adjacent areas, but can be traced into the Columbia Lava series which is so well exposed in the gorge of the Crooked River a few miles to the southeast. Since the Mascall formation overlies this lava wherever recognized, it is clear that the sediments below it can not be considered to be as young as Middle Miocene. Elsewhere in the Crooked River Basin the Columbia Lavas are most commonly found resting upon the Upper John Day beds, and all of the palaeontologic evidence indicates that this is the situation at the Brink Ranch.

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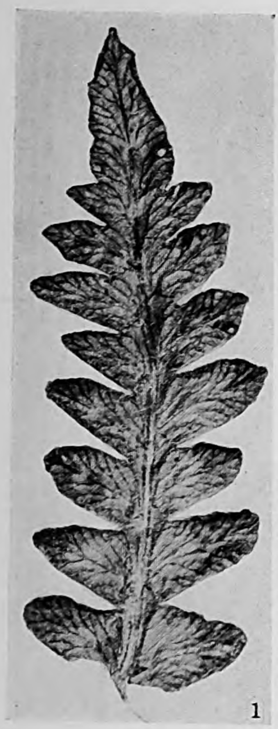
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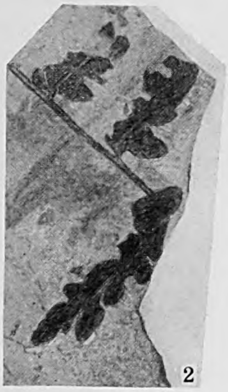
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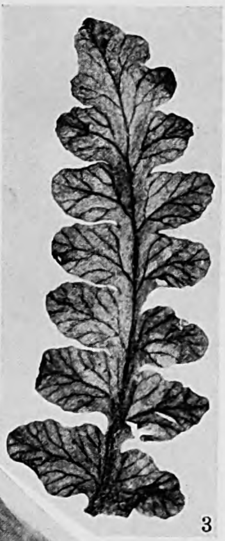
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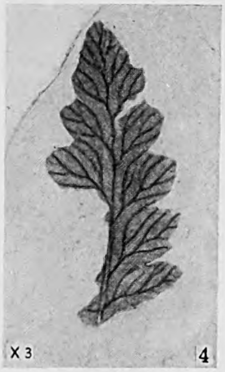

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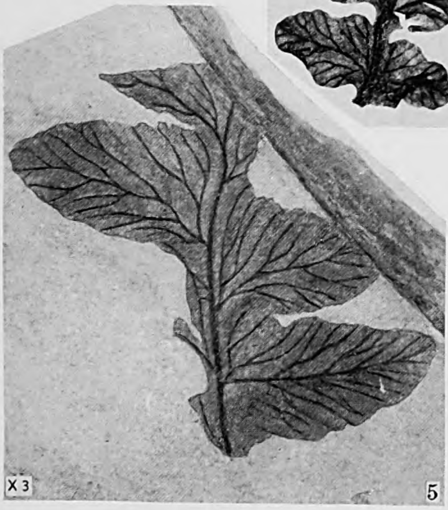

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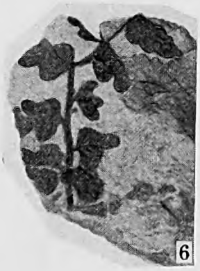
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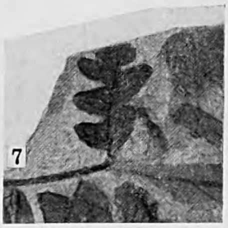
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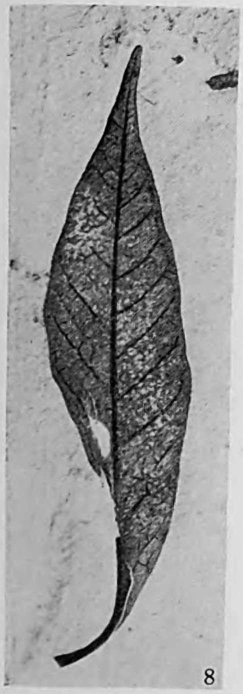
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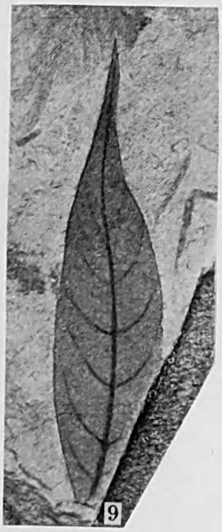
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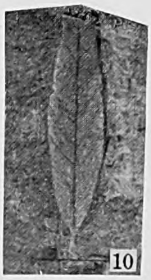
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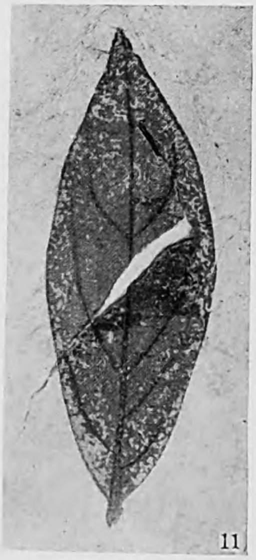
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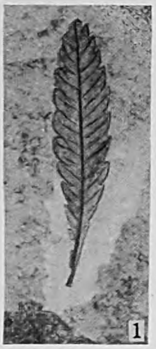
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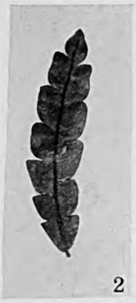
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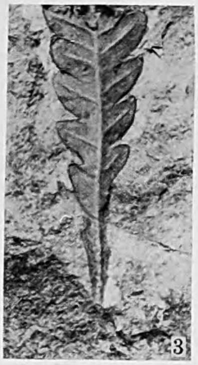
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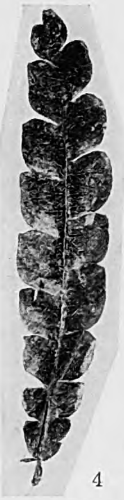
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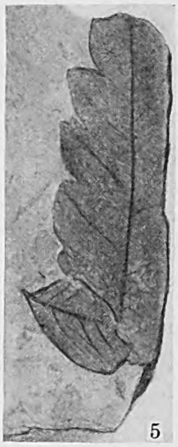
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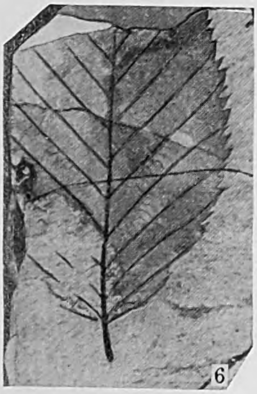
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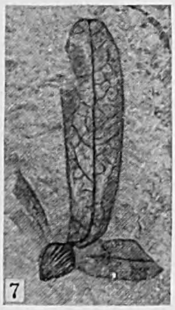
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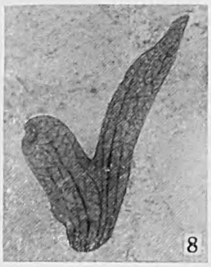
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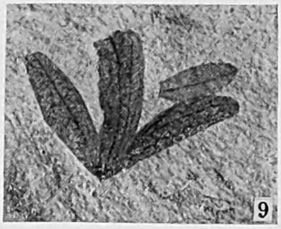
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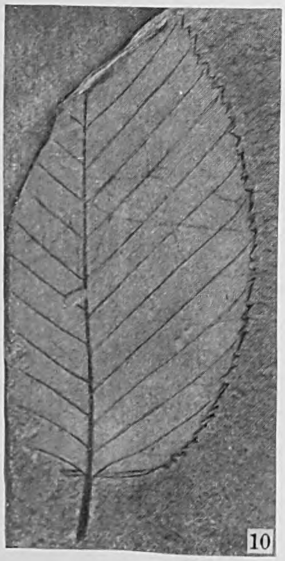
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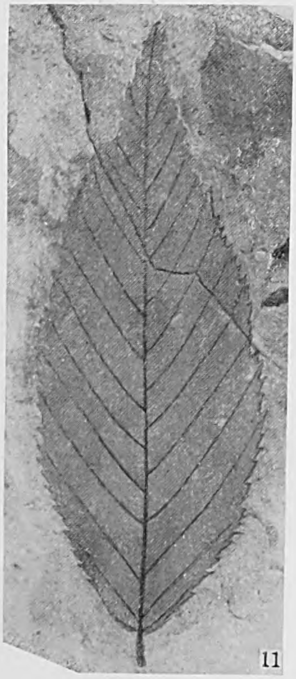
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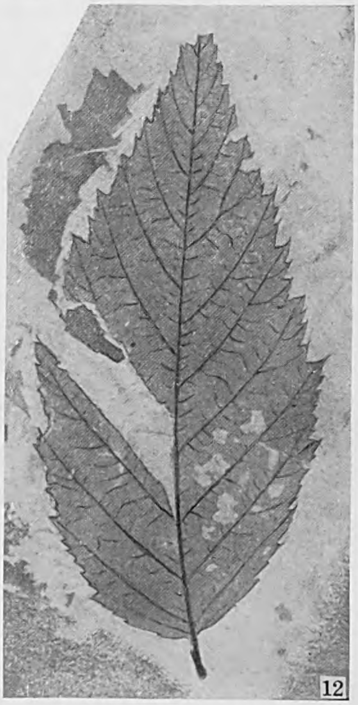
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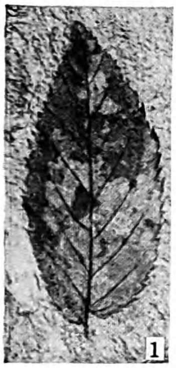
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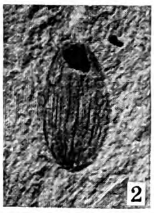
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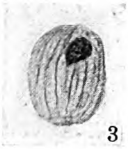
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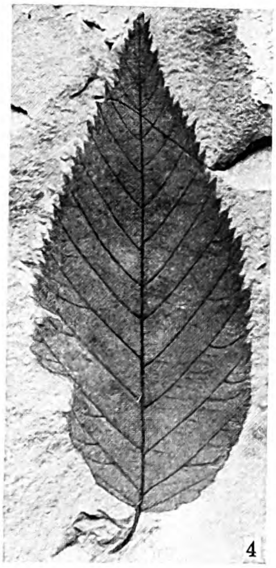
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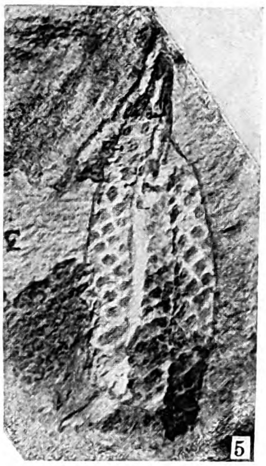
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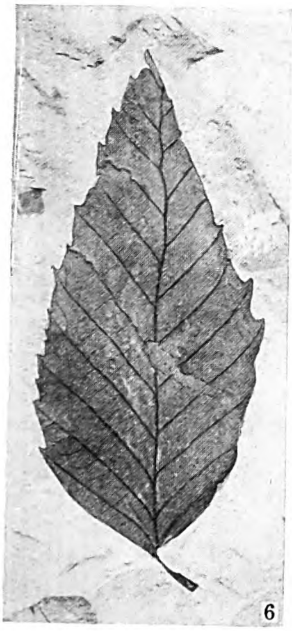
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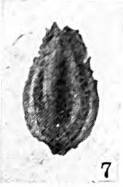
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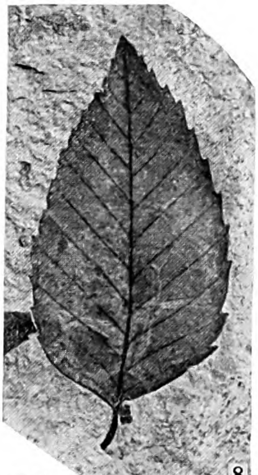
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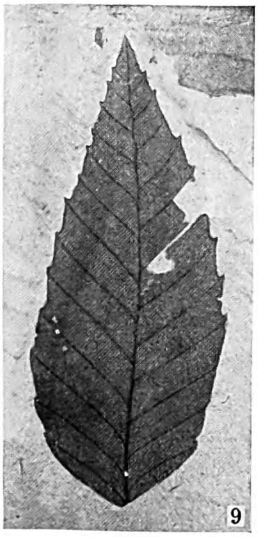
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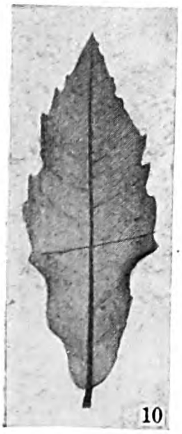
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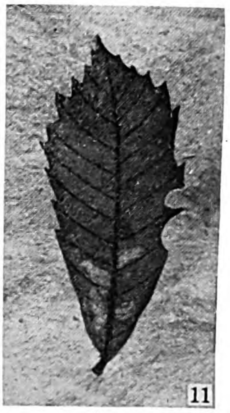
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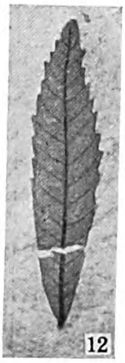
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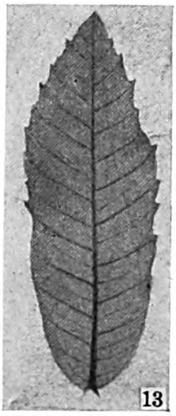
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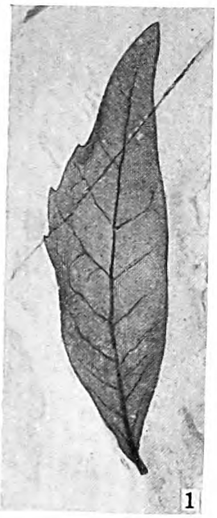
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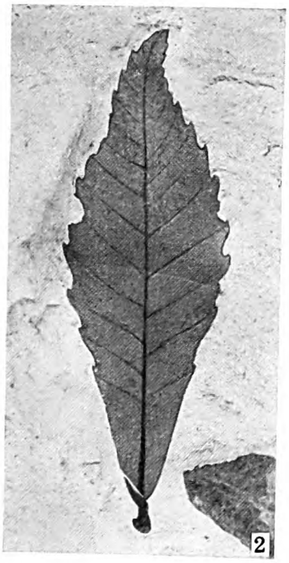
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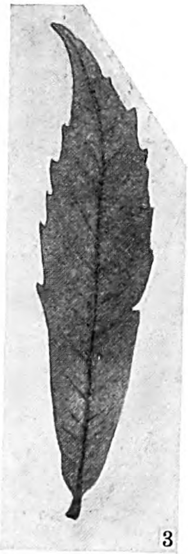
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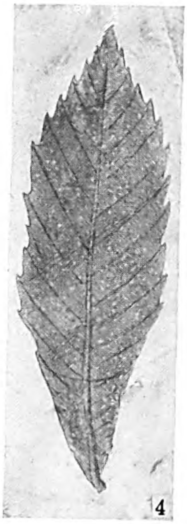
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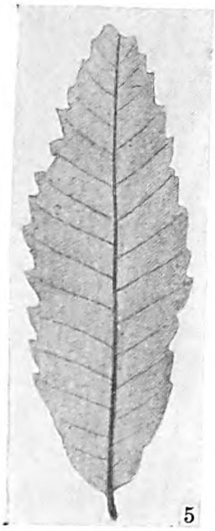
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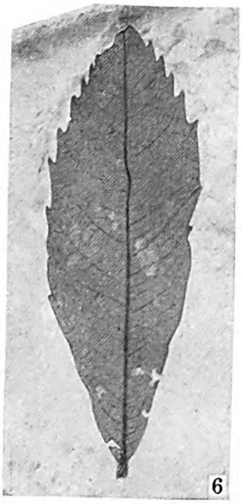
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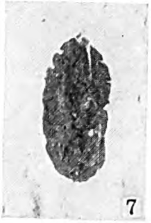
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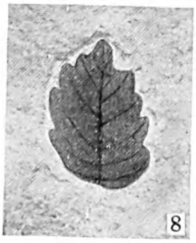
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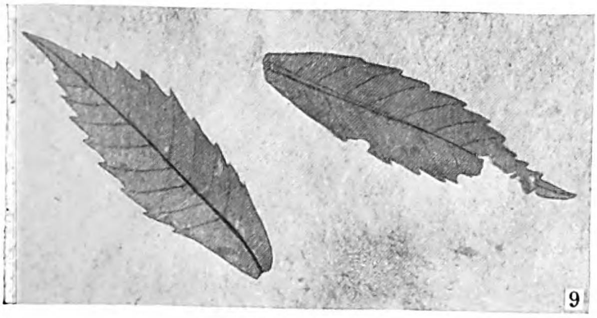
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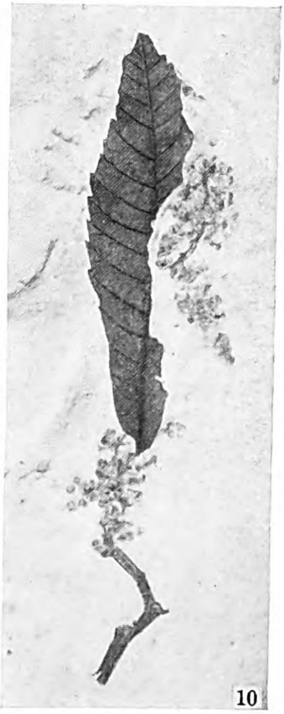
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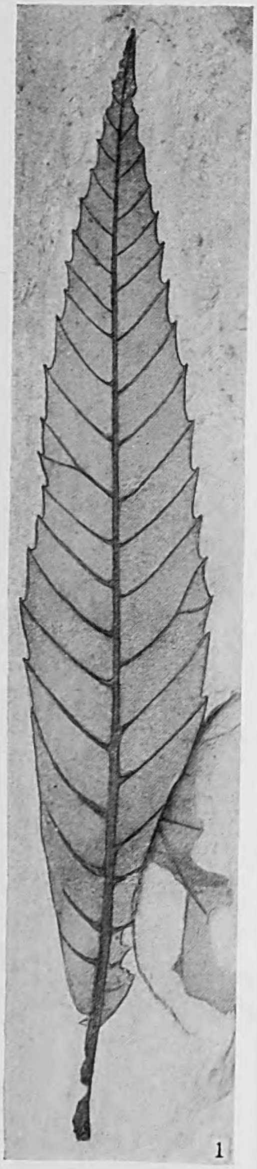
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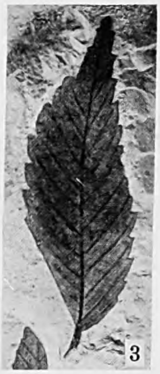
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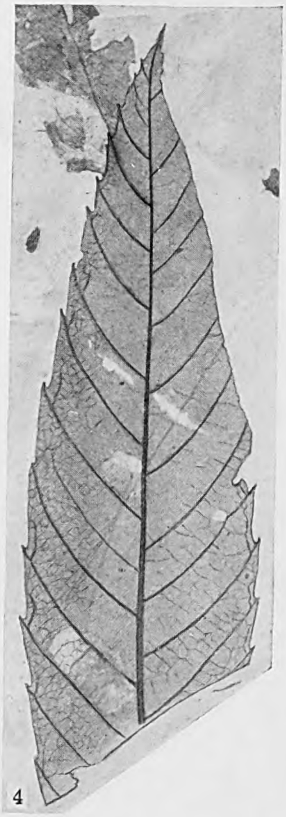
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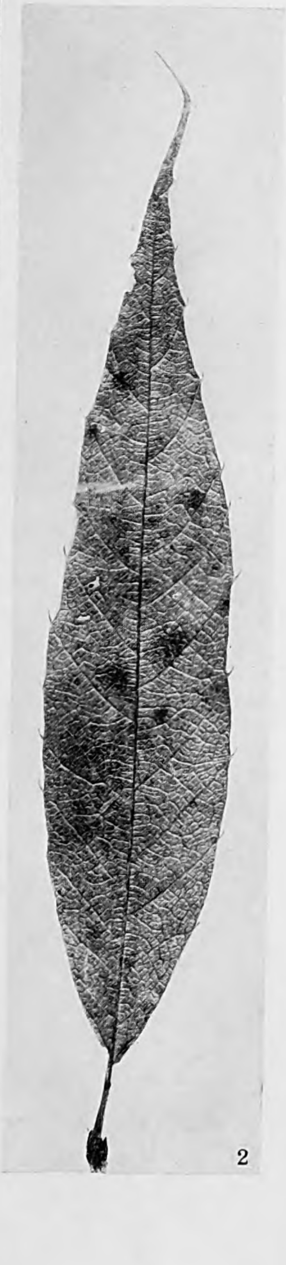
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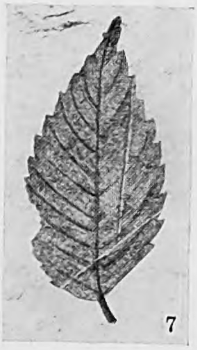
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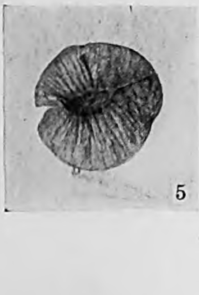
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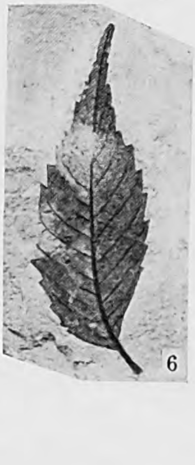
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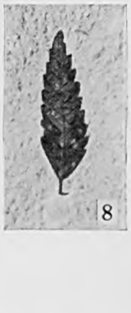
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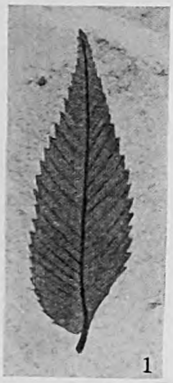
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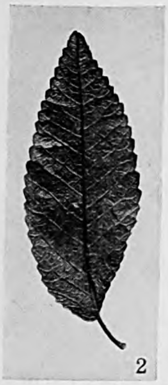
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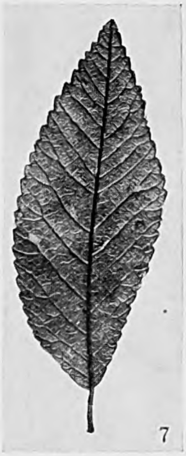
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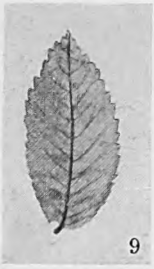
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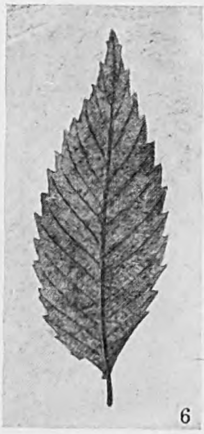
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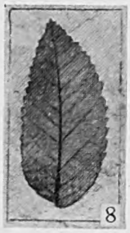
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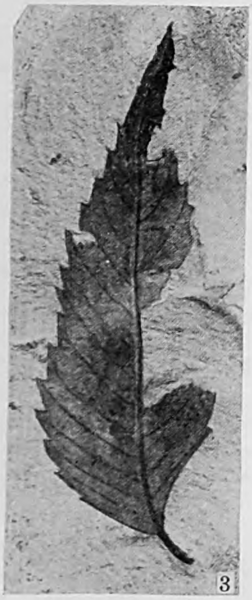
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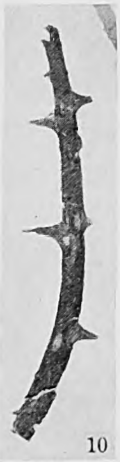
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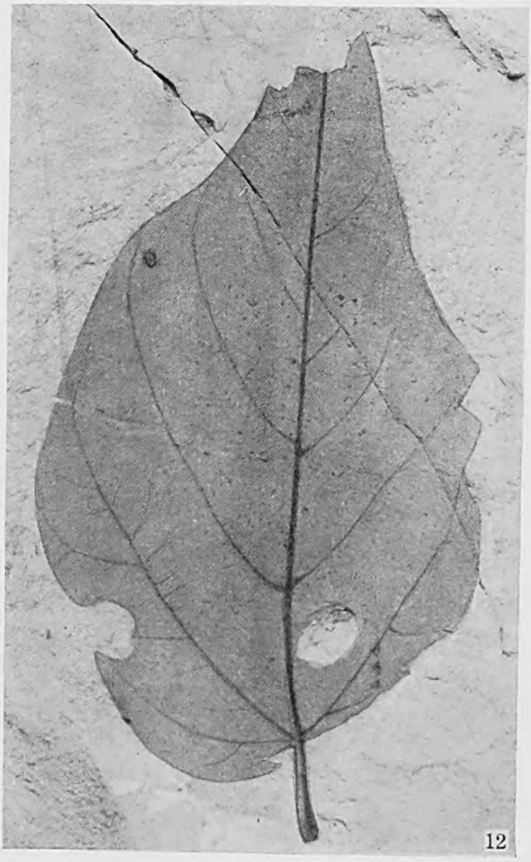
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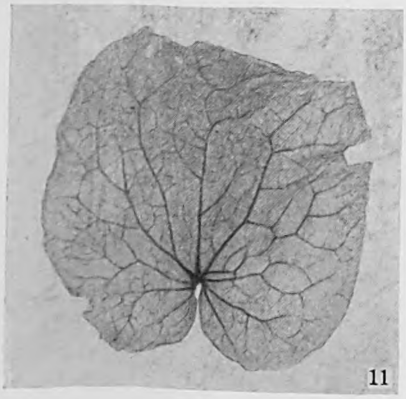
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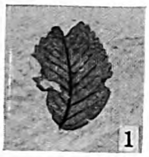
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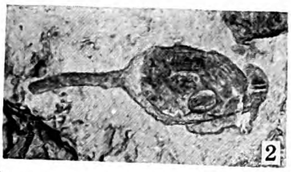
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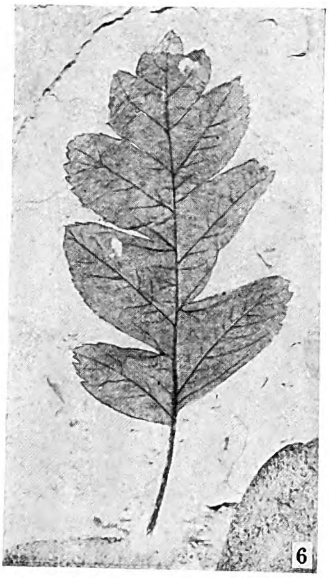
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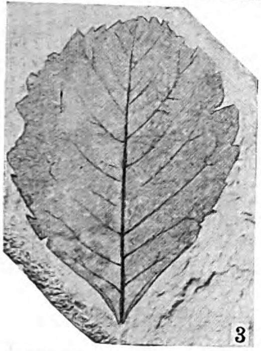
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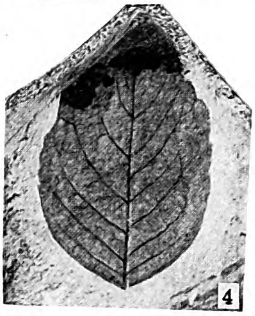
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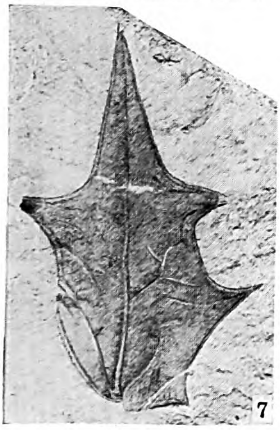
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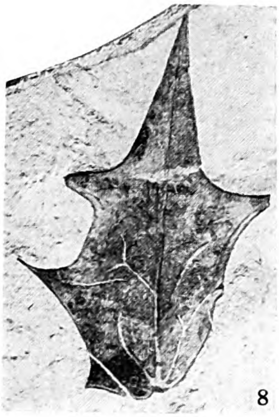
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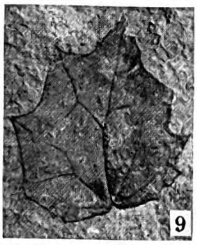
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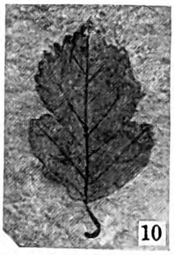
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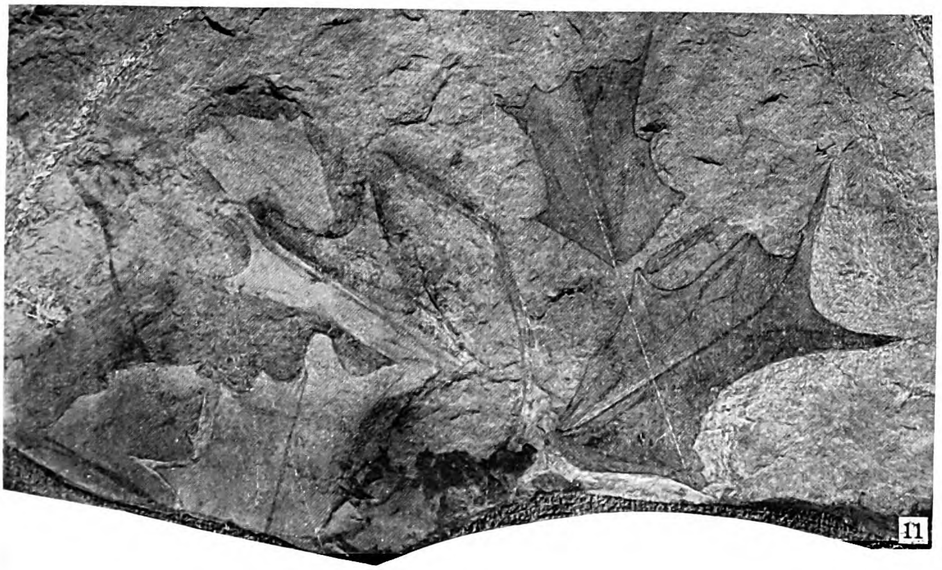
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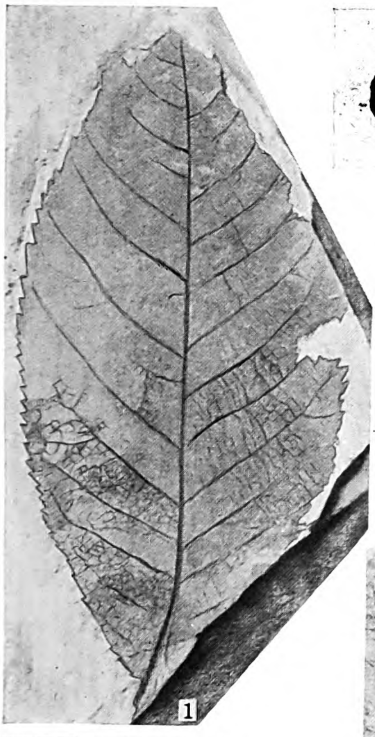
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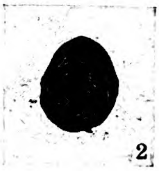
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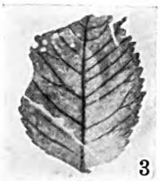
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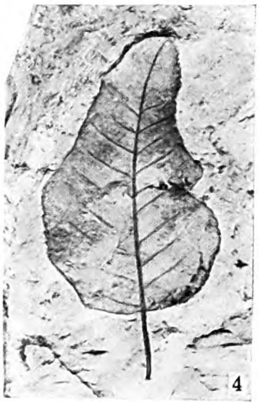
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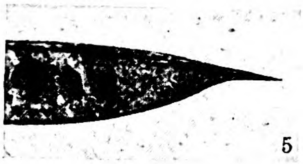
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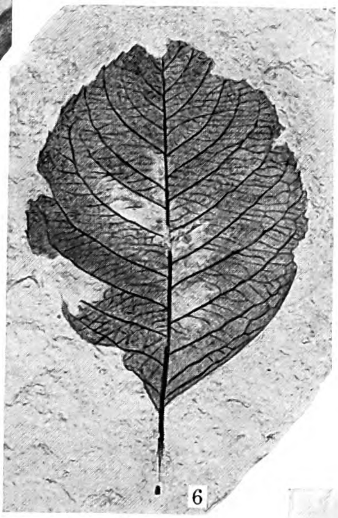
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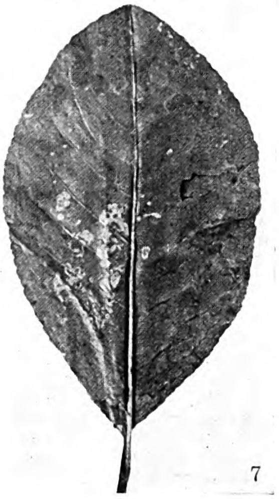
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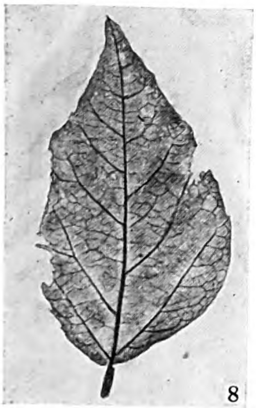
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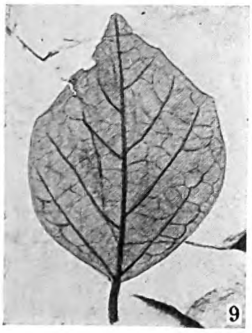
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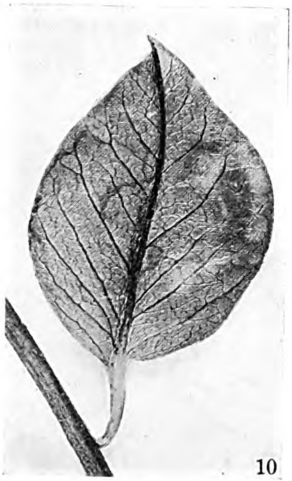
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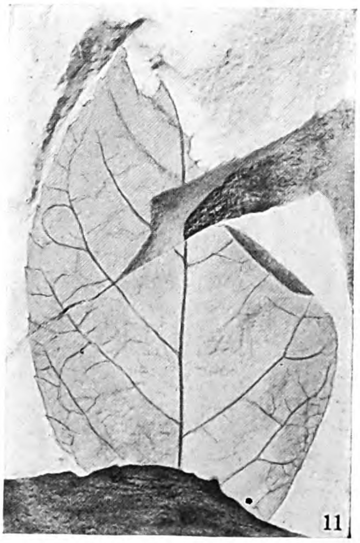
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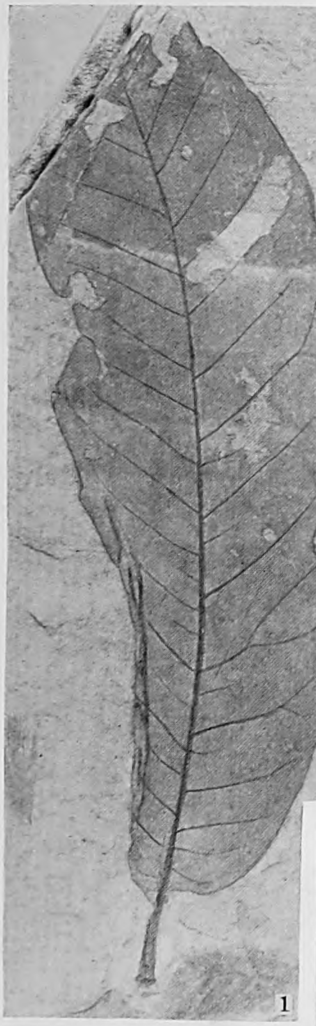
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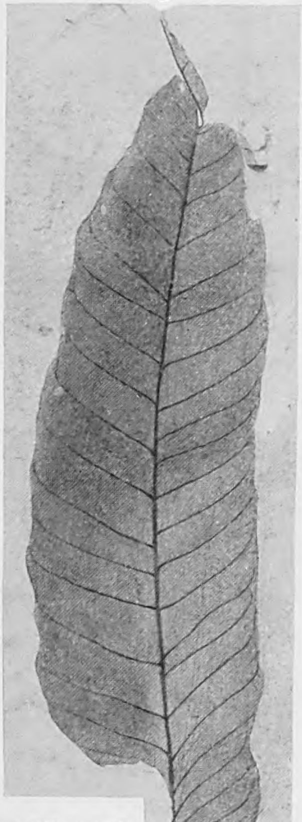
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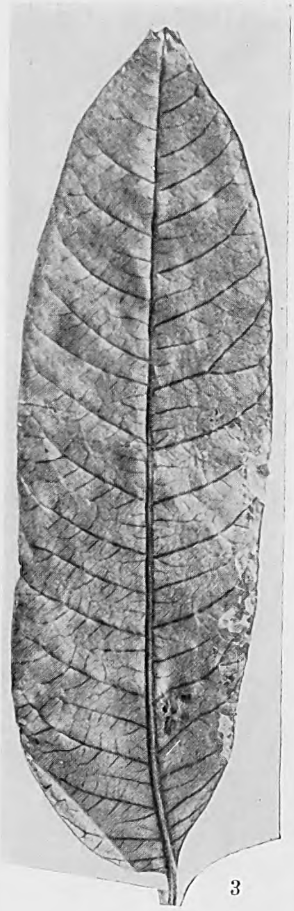
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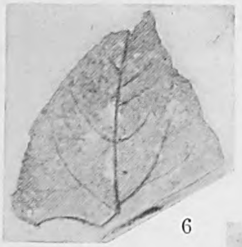
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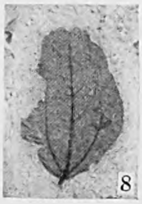
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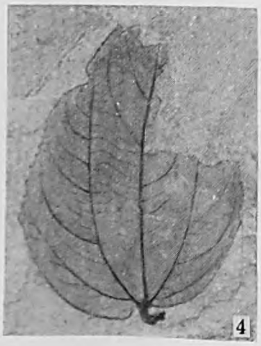
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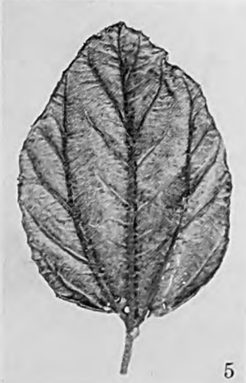
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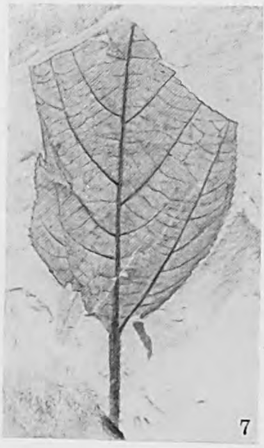
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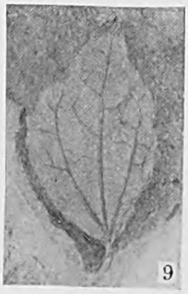
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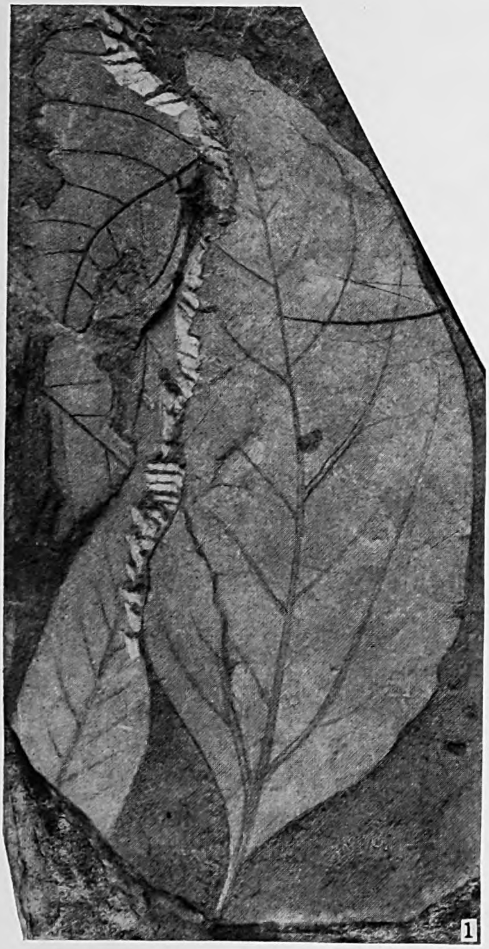
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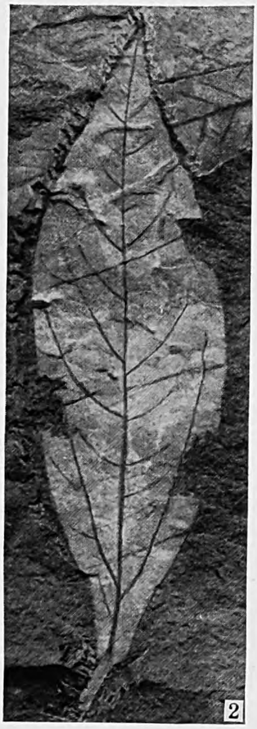
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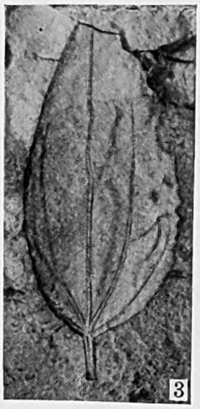
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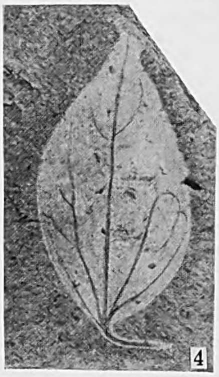
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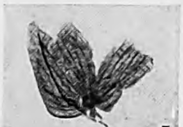
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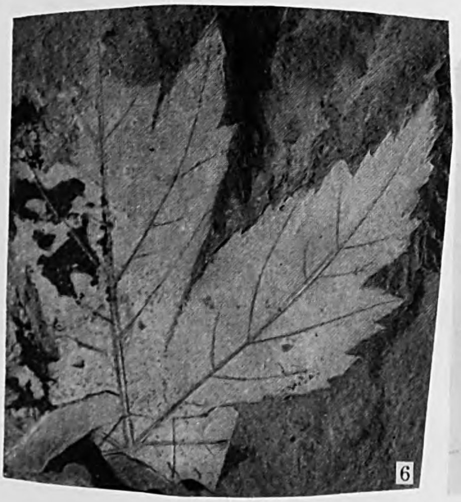
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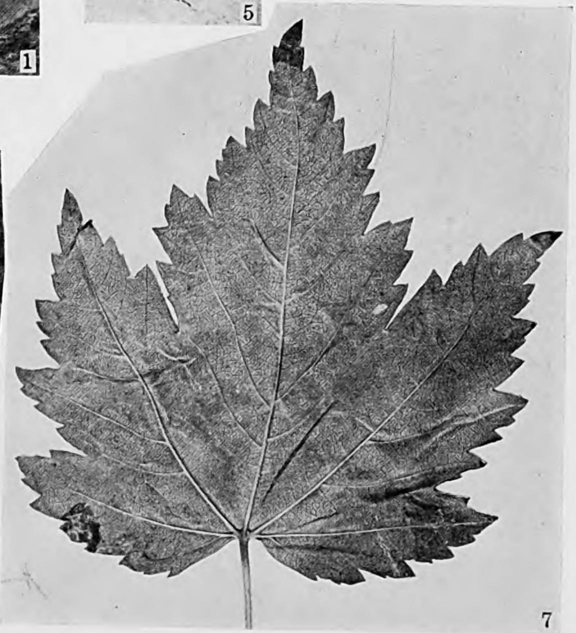
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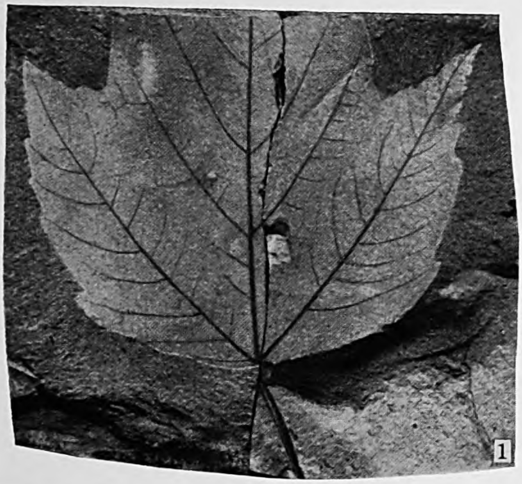
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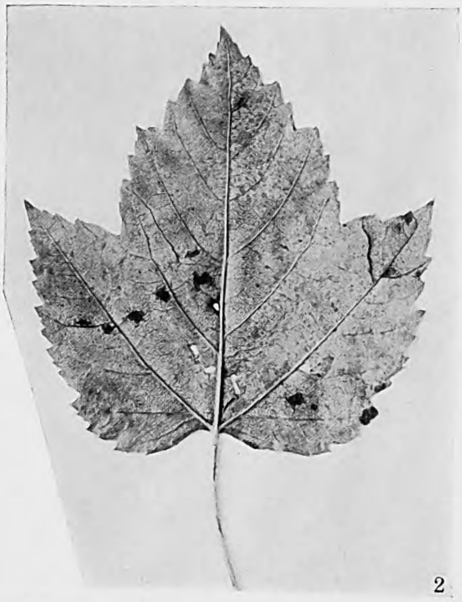
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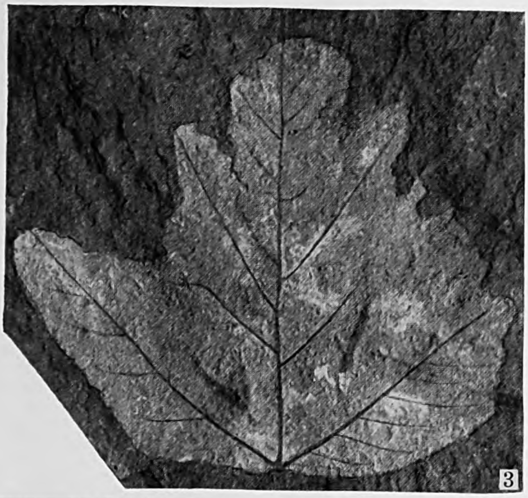
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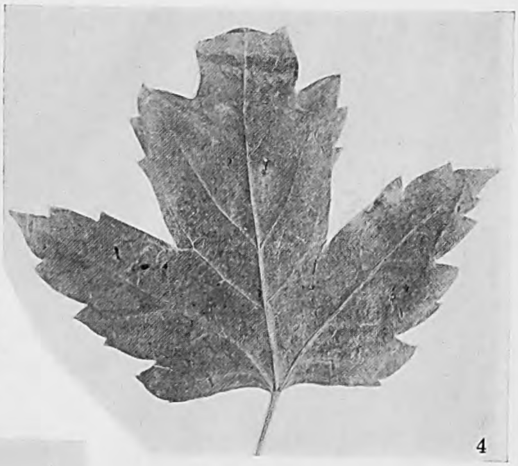
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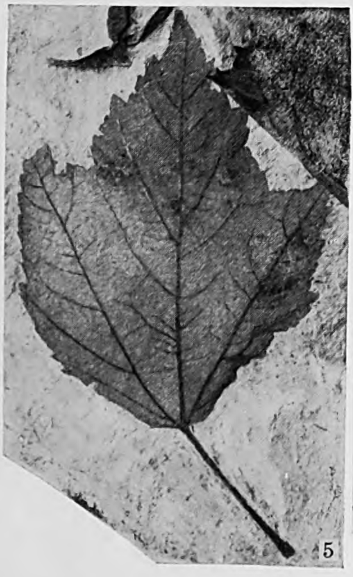
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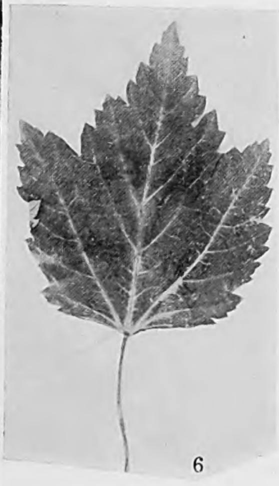
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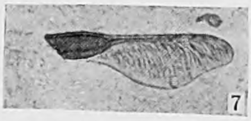
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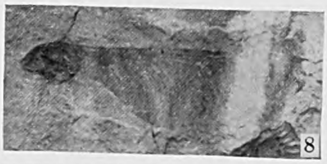
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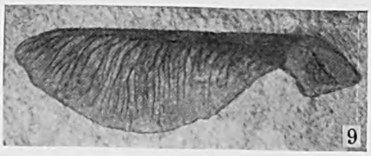
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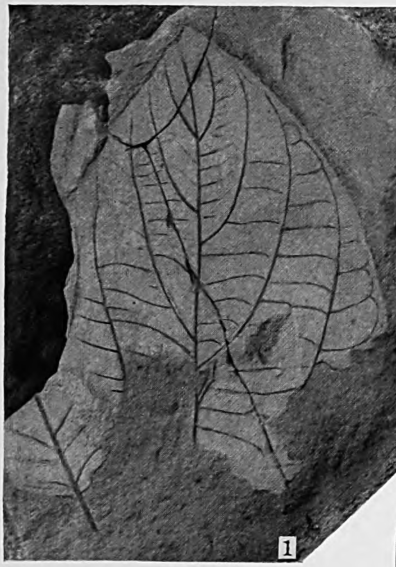
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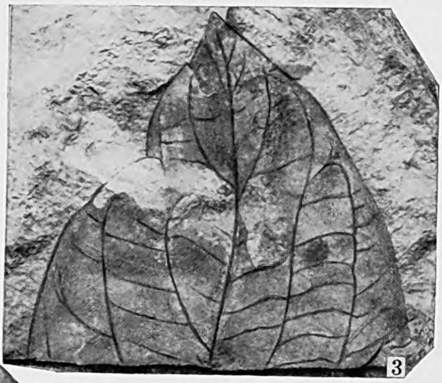
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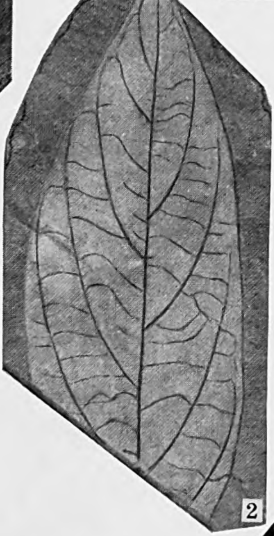
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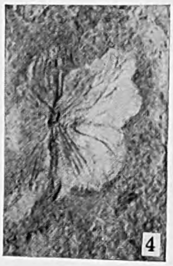
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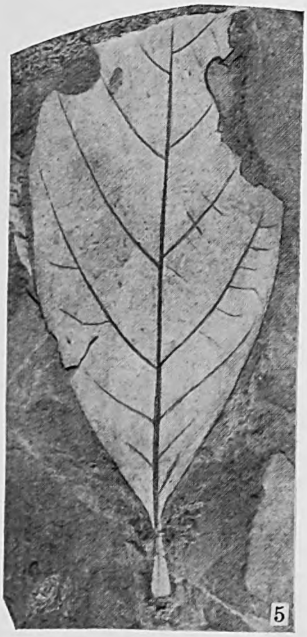
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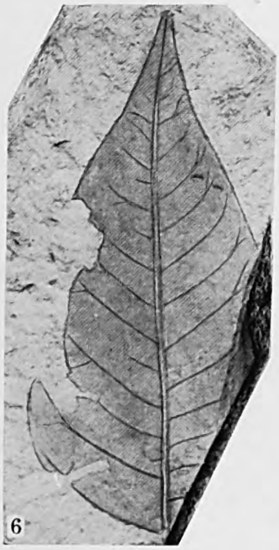
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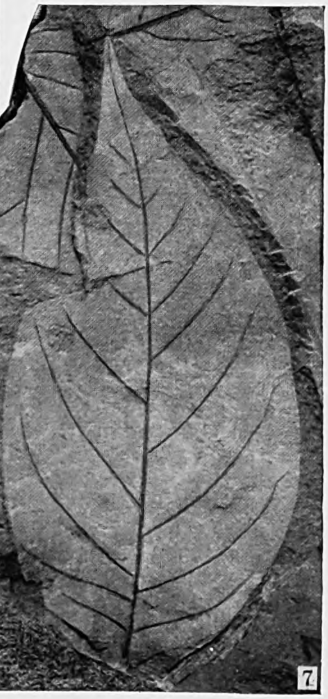
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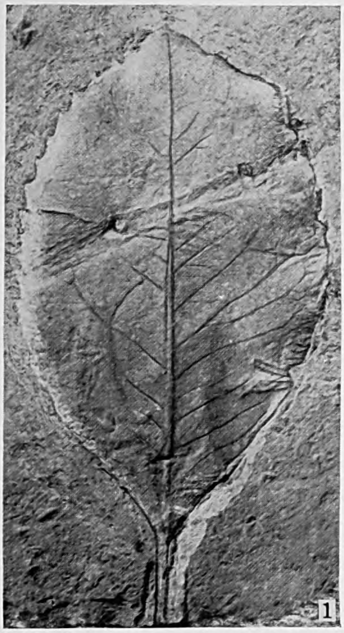
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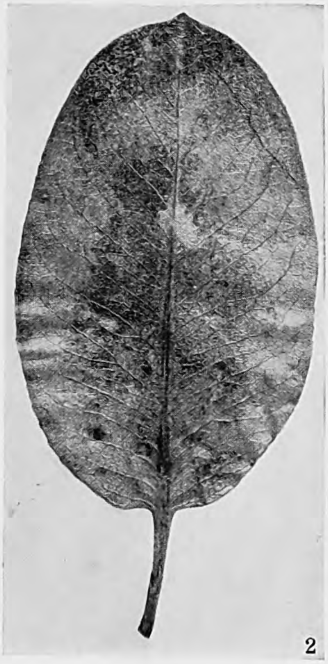
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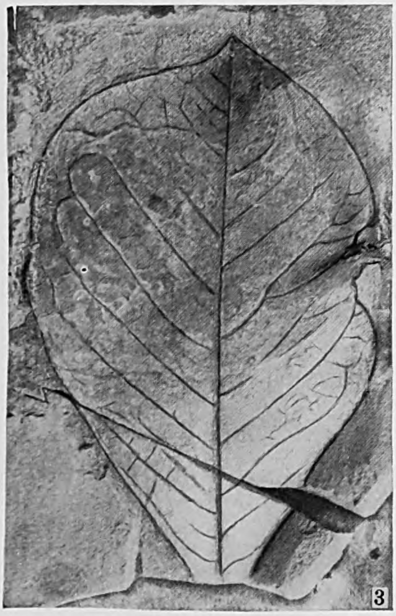
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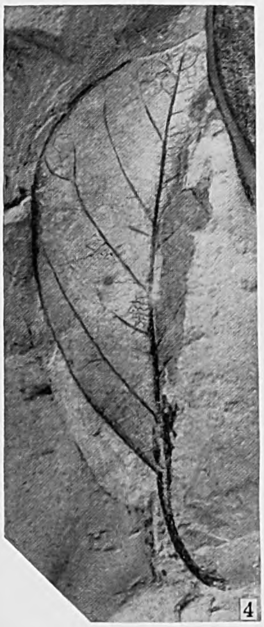
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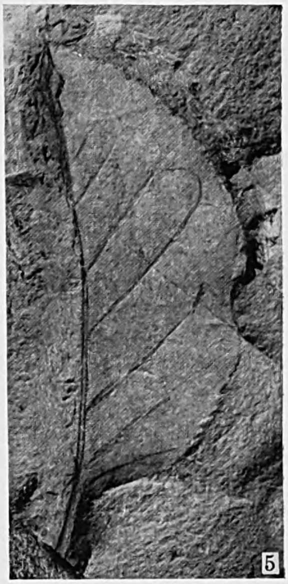
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## V

# FOSSIL RECORDS OF SOME WEST AMERICAN CONIFERS

By HERBERT L. MASON

With six plates

# V

# FOSSIL RECORDS OF SOME WEST AMERICAN CONIFERS

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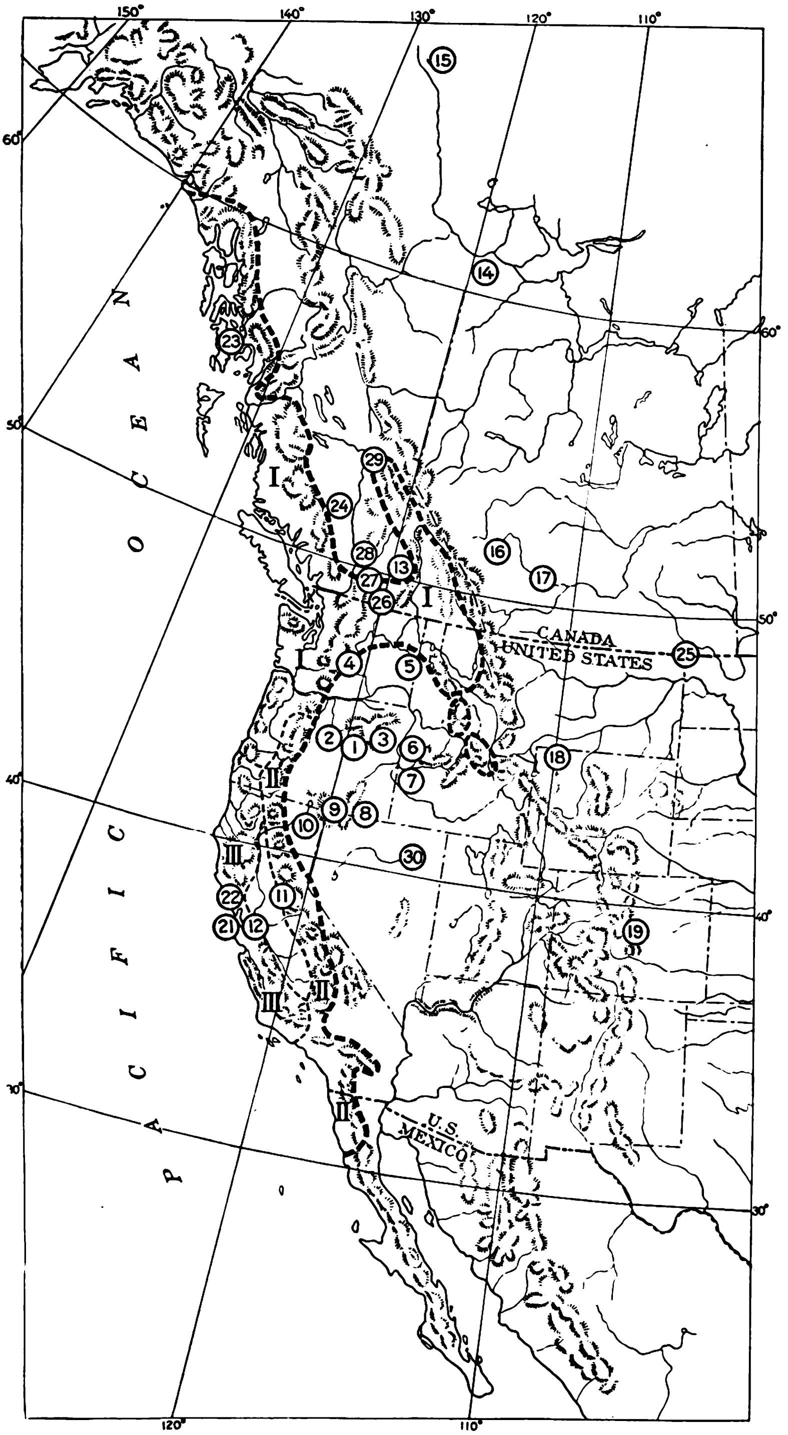
### DESCRIPTION OF MAP

Arabic numerals represent localities where dominant elements of Redwood forest have been found to occur. They represent a time range from Eocene through Pleistocene, but do not indicate a continuous forest at any one period.

1 Mascall, Miocene
2 Rock Creek, Miocene
3 Austin, Tipton Miocene
4 Ellenburg, Miocene
5 Spokane, Miocene
6 Payette, Miocene
7 Payette, Miocene
8 Malheur, Miocene
9 49 Camp, Miocene
10 Warner Mountains, Oligocene or Miocene
11 Auriferous Gravels, Miocene or Pliocene
12 Tesla, Upper Miocene
13 Kettle River, Oligocene
14 Great Slave Lake, Lower Eocene
15 Big Bear River, Lower Eocene
16 Calgary, Lower Eocene
17 Red Deer River, Lower Eocene
18 Lamar Valley, Miocene
19 Florissant, Lower Miocene
21 Merced, Pliocene or Pleistocene
22 Sonoma, Pliocene
23 Kenai in part, Miocene
24 Tranquill River, Miocene
25 Porcupine Creek, Lower Eocene
26 Similkameen, Upper Eocene
27 Tulameen, Oligocene
28 Cold Water River, Upper Eocene
29 Horsefly River, Upper Eocene
30 Elko, Oligocene or Miocene



The region outlined by the dotted line includes the living Pacific Coast Coniferous Forest which is divided as follows: (I) Northern Humid Forest, (II) Sierra-Cascade Forest, (III) California Coast Range Forest.

# FOSSIL RECORDS OF SOME WEST AMERICAN CONIFERS

By HERBERT L. MASON

## INTRODUCTION

The endemic population of the Pacific Coast Coniferous Forest makes it one of the most interesting forest assemblages extant. Nowhere is there such an abundance of coniferous species—nowhere such an assemblage of coniferous endemics.

The distribution of this forest and its endemic populations is very striking. Sargent, in a series of maps accompanying his *Report on the Forest Trees of North America,* outlines the forest as extending along the Pacific Coast from about latitude 58 in southern Alaska to Lower California. To the east it occupies the Coast Ranges and the Sierran-Cascade axis, as well as the coastal mountains of western Canada and southern Alaska. There is an eastward extension across the states of Washington and Idaho to the Selkirk and Bitter-root Mountains of western Montana. Here it again extends in a northerly and southerly direction into Alberta, Canada, and to the Bitter-root Mountains of Idaho and Montana. Outposts of the forest occur in the Bitter-root Mountains southward to the extreme northwest of Wyoming, in the higher Southern California Mountains southward to Mount San Pedro Martir in Lower California, and on the Coastal Islands, including Cedros, Guadalupe and those of Santa Barbara Channel (see map).

The relict species of this forest flora can be roughly assigned to three floral elements. These are (1) the Northwest Humid Forest, (2) The Sierran-Cascade Arid Forest, and (3) The California Coast-range Forests (see map). It is impossible to do more than arbitrarily assign the boundaries of these floral elements, because the species of one often overlaps into the area of the other. They are here considered as belonging to the area wherein they attain their best development, and are considered as outposts where they occur in other areas.

## PACIFIC COAST CONIFEROUS FOREST

### NORTHERN HUMID FOREST

This flora occupies the entire northern part of the forest area and extends south along the coast to the region north of the Rogue River in Oregon, and south in the Cascades to the vicinity of the Santiem and Mackenzie Rivers. The endemic species that attain their best development within this area are for the most part rather widespread with the exception of a small group that are scattered about timberline in the area. Those coniferous plants of general distribution in the area are: *Abies grandis, A. nobilis, A. amabilis, Picea sitchensis, Tsuga heterophylla, Larix occidentalis, Thuya plicata* and *Taxus*

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*brevifolia.* Those that are scattered about timberline are: *Pinus albicaulis, Tsuga mertensiana, Larix lyellii* and *Chamaecyparis nutkatensis.* Species extending into this flora from the outside only occur near the boundary and do not show the pecularities of distribution as do the outposts in the other floras. This area of overlap occurs in the coast ranges between the Rogue River and Coos Bay. In the Cascades it lies between the Santiem and the Mackenzie Rivers.

## SIERRA-CASCADE ARID FOREST

This flora occupies the Sierra-Cascade Mountains from the Santiem and Mackenzie Rivers region southward, including the Tehachapi Mountains and the higher mountains of Southern California and south to the San Pedro Martirs of Lower California. Outposts of the flora occur in the south Coast Ranges in the San Rafael, Santa Ynez and the Santa Lucia Mountains, and in the north Coast Ranges from Mount St. Helena to the Siskiyous and the Klamath Mountains.

Relict species of wide distribution which attain their best development within this area are: *Pinus lambertiana, P. ponderosa, P. jeffreyi, P. sabiniana, Abies magnifica, Libocedrus decurrens.* Those of isolated or scattered distribution are: *Pinus balfouriana, Abies magnifica* var. *shastensis, Sequoia giganiea, and Cupressus macnabiana* var. *nevadensis. Pinus attenuata, Torreya californica* and *Cupressus macnabiana* occur within this area as outposts from the Coast Range flora. *Pinus albicaulis, Tsuga mertensiana* and *Taxus brevifolia* occur as outposts of the Northern Humid Forest. *Pinus monticola, P. contorta, Abies concolor* and *Pseudotsuga taxifolia* are important non-endemic elements of this forest.

## CALIFORNIA COAST RANGE FOREST

The California Coast Range flora occupies the inner and outer Coast Ranges from the vicinity of the Rogue River in Oregon, south through the Santa Lucias and the San Carlos Ranges of Monterey and San Benito Counties. Outposts of the flora occur in the Santa Ynez Mountains and in isolated spots along the coast to Northern Lower California as well as on the islands off the coast of Southern and Lower California.

Relict species of wide distribution within the area are *Pinus attenuata, Sequoia sempervirens,* and to some extent *Torreya californica* and *Juniperus californica.* Endemics of scattered or isolated distribution are *Pinus torreyana, P. coulteri, P. muricata, P. radiata, Pseudotsuga macrocarpa, Picea breweri, Abies venusta, Chamaecyparis lawsoniana, Cupressus macrocarpa, C. goveniana, C. pygmaea, C. sargentii, C. macnabiana, C. forbesii, Picea sitchensis, Tsuga heterophylla, and T. mertensiana. Abies grandis* and *Thuya plicata* are in this area as outposts of the northern Humid forest. *Pinus lambertiana, P. jeffreyi, P. sabiniana, Abies magnifica* and its var. *shastensis* and *Libocedrus decurrens* occur as outposts from the Sierran-Cascade forest.

## SUMMARY

In summarizing these data it is significant to note that the northern Humid forest has 13 species that are endemic to the Pacific Coast Forest. All but 1 belong properly to the northern element. Of the 12 belonging to the area, 7 are widespread and 5 occur as timberline trees. *Pinus ponderosa* is the only species that probably typically belongs outside this area. It is so widespread that it is difficult to state exactly to which area it belongs.

The Sierran-Cascade forest has 16 species that are endemic to the Pacific Coast; 10 of these are typical of the Sierran-Cascade forest. There are 3 species that properly belong to the Northern Humid forest and 3 that belong to the California Coast Ranges. Of the 10 that properly belong to the Sierran-Cascade forest, 6 are widespread and 4 are of isolated or scattered distribution.

The California Coast Range forest has 29 species endemic to the Pacific Coast forest. Of these 17 are typical of the Coast Ranges and properly belong to them; 5 species are present that belong properly to the Northern Humid forest and 7 species that belong properly to the Sierran-Cascade Forest. Of the 17 that properly belong to this forest, 3 are widespread in parts of the area and 14 are isolated or of scattered distribution. The 5 species that come from the North and the 7 species that come from the Sierras overlap in their distribution in the area known as the Klamath Region of Northern California and Southwestern Oregon. The accompanying table summarizes the distribution and the relationships of the endemic population of the Pacific coniferous forest. The horizontal rows show the number of endemic coniferous species in each flora, and the vertical rows indicate the floral elements to which these properly belong.

Table 1—*Distributional relationships of the relict conifers of the Pacific Coast Forest*

| | Northern Humid Forest | Sierra-Cascade Forest | California Coast Range Forest |
|---|---|---|---|
| Northern Humid Forest | 12 | 1 | .............. |
| Sierra-Cascade Forest | 3 | 10 | 3 |
| California Coast Range Forest | 5 | 7 | 17 |

Table 2 summarizes the nature of the endemic species that belong properly to each floral area.

Table 2—*Nature and distribution of the relict species of the Pacific Coast Forest*

| | Wide | Narrow |
|---|---|---|
| Northern Humid Forest | 7 | 5 |
| Sierran-Cascade | 6 | 4 |
| California Coast Range | 4 | 14 |

It will thus be seen that from a point of view of relict populations the California Coast Range flora is of greatest interest both because of the large number of endemic conifers and because of the nature of their distribution.

Jepson[1] divides what he terms the "California Flora" into 10 endemic areas. Four of these occur in the Coast Ranges; these he terms the Klamath area, the Franciscan area, the Lucian area and the Santa Barbara insular area. Table 3 gives a summary of the coniferous relict populations of these endemic areas:

TABLE 3—*Distribution of the relict species in the "Endemic Areas" of the California Coast Ranges*

| | Klamath | Franciscan | Lucian | Insular |
|---|---|---|---|---|
| Pinus lambertiana | * | * | * | ......... |
| torreyana | ......... | ......... | ......... | * |
| sabiniana | ......... | * | * | ......... |
| ponderosa | * | * | * | ......... |
| jeffreyi | * | ......... | ......... | ......... |
| coulteri | ......... | ......... | * | ......... |
| attenuata | * | * | * | ......... |
| muricata | ......... | * | * | * |
| radiata | ......... | * | * | * var. |
| Abies venusta | ......... | ......... | * | ......... |
| grandis | * | ......... | ......... | ......... |
| magnifica | * | ......... | ......... | ......... |
| magnifica shastensis | * | ......... | ......... | ......... |
| Picea breweri | * | ......... | ......... | ......... |
| sitchensis | * | ......... | ......... | ......... |
| Tsuga heterophylla | * | ......... | ......... | ......... |
| mertensiana | * | ......... | ......... | ......... |
| Sequoia sempervirens | * | * | * | ......... |
| Torreya californica | ......... | * | ? | ......... |
| Taxus brevifolia | * | * | ......... | ......... |
| Libocedrus decurrens | * | ......... | * | ......... |
| Chamaecyparis lawsoniana | * | ......... | ......... | ......... |
| Thuya plicata | * | ......... | ......... | ......... |
| Juniperus californica | ......... | * | ? | ......... |
| Cupressus macrocarpa | ......... | ......... | * | ......... |
| goveniana | ......... | ......... | * | ......... |
| pygmaea | ......... | * | ......... | ......... |
| sargentii | ......... | * | * | ......... |
| macnabiana | ......... | * | ......... | ......... |
| forbesii | ......... | ......... | ......... | * |
| | 16 | 13 | 13 | 4 |

The origin of these endemic elements has been subject to a considerable amount of speculation, based largely upon the nature of the distribution of the species and to some extent upon the fossil record. This latter category of evidence has not been available until recently because the plant deposits of the west had not been sufficiently worked. Within recent years, however, palaeobotanists have begun extensive work upon these deposits and a good deal of the material is now available for study. It seems advisable at this time to place on record such data as bear upon the subject of endemism among our western conifers.

---

[1] W. L. Jepson, Manual of the Flowering Plants of California, 11, 1925.

I wish at this time to express my gratitude to Dr. R. W. Chaney, under whose direction studies were made, and to Dr. W. L. Jepson, whose helpful criticisms have been of much value.

## FOSSIL MATERIALS

The fossil materials herein cited come from Cenozoic and Quaternary deposits of western North America. They have all been studied by the writer who has made collections and field studies in the Eocene and Miocene deposits of Yellowstone National Park, the Oligocene Bridge Creek deposits and the Miocene Mascall deposits of Oregon, the Pliocene Sonoma and Merced and the Pleistocene Brea deposits of California. Studies were also made of the palaeobotanical collections in the Museum of Palaeontology of the University of California.

Determinations have been based largely upon leaves, twigs or cone materials and have been augmented by comparisons of the flora as a whole with its ecological equivalent in modern floras (see discussion under Taxodiaceae, p. 152). Where no differences are discernible the material has been referred to modern species, the modern species referred to being herein considered as relicts of Cenozoic floras. Where the material has already been cited in the literature under a name other than that of the modern species, that name is adhered to with only a mention of its probable modern reference. This policy is followed to avoid complications of synonymy until these points can be settled by a monographer.

Unless otherwise noted, all the material cited is now in the Museum of Palaeontology at the University of California.

### Family GINKGOACEAE

The Ginkgoaceae, although not coniferous and not in the living flora of North America, were present along with members of this flora in Cenozoic time. It is of interest to record it here because of the bearing it has on problems of the origin and migrations of floras.

#### Ginkgo adiantoides (Unger) Heer

(Plate 1, fig. 1)

*G. adiantiodes* (Unger) Heer. Fl. Foss. Arct., vol. 5, Abt. 3, 21, pl. II, figs. 7 to 10, 1878.

This species was present and widespread throughout the Tertiary of the Western United States. It occurs in the Mascall flora of Eastern Oregon associated with *Sequoia langsdorfii*, *Libocedrus decurrens*, *Pinus knowltoni*, *Umbellularia oregonensis* and other Redwood border species.

*Occurrence*—Mascall formation, White Hills, 12 miles east of Dayville, Oregon; Locality 3735. Eagle Creek formation, Columbia River Highway, 0.25 miles west of Bonneville, Oregon; Locality 4.

*Collection*—Univ. of California., Coll. Pal. Bot., No. 123, Locality 3735.

## Family TAXACEAE

The Taxaceae are represented in the living flora by two genera, *Taxus* and *Torreya*, each having one species. *Taxus* is distributed throughout the northern part of the forest; *Torreya* is scattered in the Coast Ranges of Central California and in the Sierra Nevada mountains.

### Taxus sp.

(Plate 1, fig. 4)

*Taxus* is doubtfully represented in the Cenozoic floras of the West by material from the Eocene reported by Penhallow and by twigs with leaves from Gray's Ranch, Crooked River, Oregon. The close resemblance of leaf impressions of this genus with those of the Taxodiaceae makes it difficult to differentiate them unless other material is available.

The material from the Gray Ranch is associated with Redwood border species which is ecologically in accord with the association of the modern *Taxus brevifolia* as it occurs in the North Coast Ranges of California.

*Occurrence*—Bridge Creek shales, lower John Day Series, Gray's Ranch, Crooked River Basin; Locality No. 3748.

*Collection*—Univ. Calif. Coll. Pal. Bot. No. 124, Locality 3748.

### Torreya sp.

(Plate 1, figs. 5, 6)

Material referable to this genus occurs in the Bridge Creek formation at Cant's Ranch, John Day Valley, about 6 miles south of Dayville, Oregon. It is composed of a series of linear lanceolate leaves 23 to 33 mm. long, somewhat rounded at the base and attenuate at the tip into a sharp point. On the lower surface are two very conspicuous stomatiferous bands.

The material is associated with Redwood forest elements, such as *Sequoia langsdorfii*, *Corylus macquarrii*, *Alnus carpinoides*, *Quercus consimilis*, *Umbellularia oregonensis* and *Odostemon simplex*. The modern *T. californica*, of which the fossil is probably the Miocene equivalent, is associated with genera whose species in many cases are hardly separable from the fossil equivalents of the Bridge Creek. These are *Sequoia sempervirens*, *Corylus rostrata*, *Alnus rubra*, *Lithocarpus densiflora*, *Umbellularia californica* and *Odostemon nervosa*.

*Occurrence*—Bridge Creek shales, Cant's Ranch, John Day Basin, 6 miles west of Dayville, Oregon; Locality 3931.

*Collection*—Univ. Calif. Coll. Pal. Bot. No. 125, Locality 3931.

## Family PINACEAE

The Pinaceae are represented in the Pacific Coast flora by six genera. They are particularly abundant in species and individuals and form the dominant forest cover of our western mountains. The majority of the species are endemic to the Pacific Coast and the few remaining are Rocky Mountain or Great Basin species. Four genera are represented in the Cenozoic floras of the West. Most of the species determinable are referable to California Coast Range species.

### Genus PINUS

The pines are an old group and were well established prior to the Jurassic. In the Cenozoic floras of the West they are represented by several species which for the most part are clearly referable to types existing today. Those which have come to my attention are all related to or referable to species that are now living in the California Coast Ranges; some are now of exceedingly limited distribution.

### Pinus torreyana Parry

(Plate 1, fig. 3; plate 2, fig. 3)

*P. torreyana* Parry, Bot. Mex. Bound., 210, pl. 58, 59, 1859.

The species is represented by two fascicles of needles, neither of which shows the entire length. The needles are in fascicles of five, exceeding 24 cm. in length and 1.5 mm. in width. The sheath is persistent, 2 to 3 cm. long.

*Pinus torreyana* is at present a very restricted endemic. It is confined to the coastal bluffs of San Diego County, California, and to Santa Rosa Island off the coast of California.

The fossil is associated with *Sequoia langsdorfii* and *Alnus carpinoides.*

Dawson[1] reports *P. trunculus* from the Miocene and Oligocene of British Columbia and refers it as possibly related to *P. torreyana.*

*Occurrence*—Bridge Creek shales, lower John Day Series, Cove Creek 5.5 miles north of Clarnos Ferry, Oregon; Locality 127.

*Collection*—Univ. Calif. Coll. Pal. Bot. No. 126, Locality 127.

### Pinus radiata Don.

(Plate 1, fig. 2)

*P. radiata* Don, Trans. Linn. Soc. 17, 441, 1836.

*Pinus radiata* is at present a coastal endemic of central western California. It occurs from Pescadero, San Mateo County, to San Simion Bay, Monterey County. A variety occurs on the coastal islands off Southern California.

Fossil cones and wood have been found in the Pliocene sandstones of the Merced and Sonoma groups. The cones are asymmetrically ovate; 8 to 12 cm. long by 5 to 8 cm. wide; scales on one side of the cones very much developed, the umbos are produced to a round knob.

Cones referable to this species have also been taken from a tar pit at Carpinteria, California. These are asymmetrically developed, the umbos on the swollen side are well rounded and broad. They average 1.02 cm. high and 2.24 cm. wide. The cones are 7.5 cm. long and 10 cm. wide at greatest opened width. The winged seeds in the cone averaged 2.71 cm. in length. The seed is 6.8 mm. long and 4 mm. wide. It is cuneate in outline, but obliquely truncated above. The wing is somewhat oblong-cuneate.

*Occurrence*—Merced sandstones, Mussel Rock, 6 miles south of San Francisco, California; Millertown formation,[2] Sonoma group, Preston Point, Marin County, California; Tar Pits, 1 mile southeast of Carpinteria, California.

*Collections*—University of California Dept. Bot. Herb.; Santa Barbara Museum of Natural History, Santa Barbara, California.

### Pinus muricata D. Don.

(Plate 3, figs. 1, 4, 5)

*P. muricata* D. Don, Trans. Linn. Soc. 17, 441, 1837; F. M. Scott, Bull. Torr. Bot. Club, 1927,
*P. attenuata* Knowlton, Jour. Wash. Acad. Sci. 6, 85, 1916.

Three cones from the Pleistocene tar pits at Rancho La Brea are referable to this species. The material is thoroughly impregnated with oil, thereby preserving the minutest details of structure. The cone is asymmetrically ovate, 72 mm. long. The umbos on the swollen side are produced and bear evidence of having been terminated with a prickle.

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[1] J. W. Dawson, Roy. Soc. Canada, Trans., vol. 8, sec. 4, 78, fig. 5, 1888.

[2] R. E. Dickerson, Calif. Acad. Sci. Proc., Vol. 19, No. 19, 1922.

Associated with it in the tar pits are *Cupressus macrocarpa*, *Juniperus californica*, *Quercus agrifolia* and *Xanthium calvum*. Of these *Cupressus macrocarpa* and *Quercus agrifolia* are also near associates of the living plant.

Similar cones occur in the tar pits recently discovered at Carpinteria, California. These are somewhat smaller than those at La Brea but are clearly referable to the same species. They are asymmetrically ovate in outline, 6.47 cm. long by 6.85 cm. wide at the greatest opened width. The umbos on the swollen side are produced and somewhat recurved. Seeds are abundant, and are 1 to 1.5 cm. long including the wing. The seed is 5 mm. long by 3 mm. wide, flattened; obovate in outline but obliquely truncated above.

Fragments of needles occur in the deposits. These are not complete but are sufficient to show that they occurred in fascicles of 2.

*Pinus muricata* is at present a relict with a scattered distribution. It ranges from Fort Bragg, Mendocino County, California, to north of San Quentin and on Cedrus Island, Lower California. It rarely reaches much more than a few miles inland from the sea—reaching to a distance of 10 miles inland on the summit of La Purissima Hills near Lompoc, Santa Barbara County, California.

*Occurrence*—Tar pits, Rancho La Brea, Los Angeles County, California; Locality 9. H 13, 17 ft. and J 14, 12 ft. Tar pits 1 mile southeast of Carpinteria, Santa Barbara County, California.

*Collections*—Los Angeles Museum, Santa Barbara Museum of Natural History, Santa Barbara, California.

### Pinus knowltoni Chaney

(Plate 2, fig. 1; plate 3, figs. 3, 6, 7)

*P. knowltoni* Chaney, Contr. Walker Mus., 2, 5, 160, 1920.

*P. knowltoni* is probably referable to the modern *P. attenuata*. It is represented by casts of leaf and cone material, but the fragmentary nature of the latter does not warrant a positive statement as to its inclusion in the modern *P. attenuata*. The needles are in fascicles of three. The cone is attenuate and narrow and apparently asymmetrically developed. This latter characteristic is not very obvious and is therefore subject to some doubt. The nature of the cone scale processes are those of the closed cone pines.

The plant was associated with the Redwood border species of the Mascall flora, which is ecologically similar to the habitat of *P. attenuata* of the Coast Ranges of California.

It is reported from the Mascall of Oregon, the Payette flora of Eastern Oregon and adjacent Idaho, and from the Eagle Creek flora along the Columbia River in Oregon.

*Occurrence*—Mascall formation. Railroad cut 1 mile southeast of Tipton, Oregon, Locality 3336.

*Collection*—Univ. of Calif. Pal. Bot., Loc. 3336, No. 128.

### Pinus attenuata Lemmon

(Plate 2, fig. 2)

*P. attenuata* Lem., Gard. & Forest, 5, 65, 1892.

*Pinus attenuata* is a member of the closed cone group of pines and is one of the most abundant and widespread of that group in western America. It is particularly abundant in the Coast Ranges, but only of scattered distribution in the Sierra Nevada and the Cascade Mountains.

A cone of almost unaltered preservation referable to this species was taken from deposits known as the Auriferous Gravels. It occurs 10 feet below the surface in gravels capped by ferruginous conglomerate. Its age is probably Pliocene but may be as recent as Pleistocene. The cone is 9.5 cm. long and 6.8 cm. wide. It is asymmetrical and has the umbos of the scales on one side produced to an attenuate knob. There appear to be no differences between this cone and living material of this species.

Associated with it in the gravels is unaltered wood of *Sequoia* as well as fragments that are slightly carbonized. Seed referable to the genus *Arctostaphylos* also was found in the bed.

*Occurrence*—Auriferous Gravels, You Bet, near Grass Valley, California.

*Collection*—Univ. Calif. Pal. Bot. Coll., No. 133.

### Genus ABIES

The genus *Abies* is represented on the Pacific slope by seven species. They range from the Transition through the Canadian and Hudsonian zones. With the exception of *Abies concolor* and *Abies lasiocarpa*, all lie within the limits of the Pacific Coast coniferous forest and occur chiefly in the Canadian and Hudsonian zones.

Outstanding among them is the Santa Lucia Fir (*Abies venusta* Koch) which is geographically isolated from all other species of the genus by a distance of 225 miles to the north, 120 miles northeast and 149 miles east. It is peculiar in the genus, both in the nature of its cone structures and in the character of its needles. It is the only species of the genus that approaches the Sonoran zone in its distribution. However, it belongs typically to the Transition zone. It occurs only in the Santa Lucia Mountains of California and is associated with Redwood border species.

Another outstanding member of the genus is *Abies magnifica* var. *shastensis.* It occurs at much higher altitudes than does *A. venusta* and is separated from it by a distance exceeding 200 miles. It, however, has not such restricted distribution as does *A. venusta.* It occurs sparsely scattered on west slopes of the Sierra Nevada Mountains and southern Cascades as well as in the coastal mountains of northern California and southern Oregon. Aside from the general generic characteristics, it has in common with *A. venusta* only the exserted bracts which it shares also with *A. nobilis* of the North. These, however, differ very markedly in the respective species.

Fossil records of this genus in the Western United States are chiefly from the Jurassic. There is an Eocene record from the Livingston in Montana. None of these seem referable to any living species. A survey of materials from the Cenozoic deposits of the West discloses the following as referable to the genus.

### Abies chaneyi sp. nov.

(Plate 4, figs. 1, 2, 7)

Leaves sessile (leaving an evident round scar where removed), slender, 5.5 cm. long by 2 to 2.5 mm. wide, somewhat incurved toward the apex of the branch, appearing stomatiferous on the lower surface only, tip long pungent-acuminate 2 mm., leaf scar evident circular; bract exserted, acuminate, tapering to a long linear tip, scale 22 mm. wide by 10 mm. long, rounded at the apex, abruptly narrowed below to a short stalk 8 mm. long; seed and wing 2 cm. long, wing oblong-obovate, clasping the seed on one side; expanded portion 12 mm. at greatest length and 7 mm. at greatest width.

The specimens examined include the two faces of a twig 4 dm. long with a seed imbedded near the base, 2 scales with their appended bracts and several loose needles. The material is all at University of California Museum of Palaeontology.

*Abies chaneyi* seems most closely referable to the modern species *A. venusta*, but differing from it in several minor respects. The long linear bract, the pungent leaves and the seed show striking relationships. The bract, however, differs from the living species in not having the two lateral appendages near the base. The leaves are somewhat more slender. As yet no differences have been detected in the seed. The narrow wing of the seed and the pungent tip of the leaf are not the common types for such structures in the genus.

The modern species is a very narrow endemic, being limited in its distribution to the Santa Lucia Mountains of Monterey County, California. The ecological position of *A. venusta* is probably very similar to that of the fossil *A. chaneyi* as a comparison of the associated genera and species will show:

| *Modern Species:* | *Fossil Species:* |
|---|---|
| Abies venusta | Abies chaneyi |
| Acer macrophyllum | Acer bolanderi |
| Alnus rhombifolia | Alnus carpinoides |
| Arbutus menziesii | Arbutus matthesii |
| Libocedrus decurrens | Libocedrus decurrens |
| Lithocarpus densiflorus | Quercus (Lithocarpus) consimilis[1] |
| Pinus attenuata | Pinus knowltoni |
| Quercus agrifolia | Quercus convexa |
| Quercus kelloggii | Quercus pseudo lyrata |
| Sequoia sempervirens | Sequoia langsdorfii |
| Umbellularia californica | Umbellularia oregonensis |

*Occurrence*—Mascall formation, White Hills, John Day Basin, 13 miles east of Dayville, Oregon.

*Collections*—Univ. Calif. Coll. Pal. Bot., Nos. 134, 135, 136. Locality 3735.

### Abies magnifica var. shastensis Lemmon

(Plate 4, figs. 6, 7)

*A. magnifica var shastensis* Lem., Rept. Cal. State Board Forestry, 3, 145, 1890.

This variety is represented by a scale with its bract and a seed. The scale is 24 mm. wide by 16 mm. long, the stalk being 7 mm. long; the expanded portion of the scale is somewhat cordate at the base. The seed is asymmetrically cuneate with a broad wing 19 mm. long by 14 mm. wide at the top.

Although the material is meager, the size and the shape of the scale and the bract, as well as the size and the shape of the seed and wing, would warrant its inclusion in this living variety of *Abies magnifica.* There are, however, elements of the habitat of the fossil that might argue against such a conclusion. The associates of the fossil plant are those species of the Redwood border forest as outlined by Chaney, and included in this deposit are such forms as *Abies chaneyi, Pinus attentuata, Sequoia langsdorfii, Libocedrus decurrens, Alnus carpinoides, Umbellularia oregonensis,* etc. Only in its lower limits in the coastal mountains of California does the living form approach the Transition zone. Here it is found associated with *Pseudotsuga taxifolia, Pinus ponderosa, P. attenuata, P. lambertiana* and *Libocedrus decurrens.* The center of its distribution is out of this zone. It ranges from Upper Transition to almost timberline, and is found associated with *Abies magnifica, Pinus monticola* and *Pinus contorta.* It seems probable that its presence in a deposit with the Redwood border forest may represent an extra-limital distribution in past times as does its occurrence in the transition zone in the northern coastal mountains today.

*Occurrence*—White Hills locality of the Mascall formation, 13 miles east Dayville, John Day Basin, Oregon.

*Collection*—Univ. Calif. Coll. Pal. Bot., Nos. 139, 151, Locality 3735.

There are two other specimens in the collections at the University of California that are referable to the genus *Abies.* In the absence of more critical material these can only be referred to the genus and designated as follows.

[1] It seems probable that *Quercus consimilis* is referable to *Lithocarpus* but in the absence of data upon which to base definite proof it seems advisable only to suggest a relationship here.

### Abies sp. 1

(Plate 4, fig. 4)

This species is represented only by a seed, 16 mm. long. The wing, instead of being asymmetrically cuneate, is almost orbicular above the seed. It is found in the White Hills locality of the Mascall associated with *Abies chaneyi* and *Abies magnifica* var. *shastensis* as well as the more important Redwood border elements.

### Abies sp. 2

(Plate 4, fig. 3)

This species is represented by several specimens of loose needles and as such is not referable to any particular species.

The material occurs in the Gray Ranch locality along the Crooked River, about 40 miles above Prineville, Oregon. It is associated with *Sequoia langsdorfii*, *Alnus carpinoides*, *Quercus clarnensis*, *Umbellularia oregonensis*, *Acer osmonti* and *Odostemon simplex*.

## Genus PICEA

(Plate 3, fig. 2)

The genus *Picea* is represented in the Pacific Coast coniferous forest by 5 species. They are chiefly elements of the Northern Humid forest. Penhallow[1] records 2 species from the Miocene of British Columbia and 1 from the Oligocene. In the Mascall (Miocene) of Oregon the genus is represented by a single twig whose preservation is of such nature as to make it impossible to refer it to a species. The twig is 5 cm. long and the peg-like leaf traces are spirally arranged.

*Occurrence*—In the Mascall formation. Railroad cut 1 mile southeast of Tipton, Oregon. Locality 3936.

*Collection*—Univ. of Calif., Pal. Bot. No. 127, Locality 3936.

## Genus PSEUDOTSUGA

*Pseudotsuga* is represented in the Pacific Coast flora by 2 species; one is limited to the southern California mountains, the other is widespread along the coast and in the Sierra Nevadas and Cascade Mountains. The southern California *P. macrocarpa* is reported by Penhallow from the Mad River in Humboldt County, but from his discussion it seems more likely that his material is referable to *P. taxifolia*. He cites his material as being identical with the living species that is abundant on the adjacent hillsides. *P. macrocarpa* does not occur within 450 miles of the fossil deposit. Penhallow also records *P. miocena* from the Eocene of Saskatchewan and the Miocene of British Columbia. This material has not been seen by the writer.

### P. taxifolia Britton

***P. taxifolia*** **Britton, Trans. N. Y. Acad. Sci., vol. 8, 74, 1889.**

Material referable to this species has been recorded from Pliocene deposits in central California. A poorly preserved cone was referred here from the Santa Clara formation by Hannibal[2] and a series of cones from the Merced sandstones were referred here by Lawson.[3] The cones from the Merced sandstones are somewhat carbonized. The deposit is probably lacustrine as these sediments are marine.

*Occurrence*—Merced sandstones Mussel Rock, along coast 6 miles south of San Francisco.

*Collection*—Univ. of Calif., Pal. Bot. No. 152.

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[1] D. P. Penhallow, Roy. Soc. Canada Trans., 2d. ser., vol. 10, sec. 4, 70, 1904.

[2] H. Hannibal, Bull. Torr. Botanical Club, vol. 38, 338, 1911.

[3] A. C. Lawson, Univ. Calif. Bull. Dept. Geol., vol. 1, 146, 1893.

## Family TAXODIACEAE

The members of the *Taxidiaceae*, particularly the genera *Sequoia*, *Taxodium* and *Glyptostrobus*, have been subject to most diverse and confusing treatments by palaeobotanists. The antiquity of the genera and their great geographic range in past time has resulted in a tremendous range of variation in their respective species. This, coupled with the close resemblance of the vegetative form of the genera, has perhaps been the largest contributing factor to the present confusion within the family. To differentiate between the leaf imprints of these genera is a difficult problem and as yet has not been satisfactorily done. Various methods have been suggested, but all so far presented can be broken down by the range of variation within the single species *Sequoia sempervirens*.

In view of these facts it seems well to supplement the characteristics of the gross morphology of the twigs with data derived from a consideration of the ecological relationships of the modern representatives of the genera. This method was first suggested by Clements[1] and further elaborated by Chaney[2] and seems to be an excellent working hypothesis in the treatment of at least the later Cenozoic floras.

As pointed out in the species so far dealt with, most of them are associated in a flora that is ecologically equivalent to the modern Redwood flora or to the Redwood border flora. Can we logically expect to find *Taxodium* or *Glyptostrobus* in a floral association which is essentially that of the modern Redwood forest of *Sequoia sempervirens?*

Chaney, in comparing the Bridge Creek flora with the modern Redwood forest, notes its similarity in the aggregate, but also records the presence of a certain number of species that are not at present found associated with *Sequoia*. Nor are they to be found in the western United States. They are all closely related to species that occur in the southeastern United States and are often associated with *Taxodium distichum*. Again in his treatment of the Mascall flora,[3] he finds it comparable to the "Oak-Madrone"[4] or the Redwood Border forest in the aggregate, and again records the presence of a certain small element that does not at present occur in these associations but occurs in the southeastern United States as well as a certain few occurring in China. These facts have a very significant bearing on the determination of the taxodiaceous plants of our western fossil floras. Although *Taxodium* grows in swamps and upon wet land, it also occurs associated with plants, such as hickories and maples which do not grow in standing water. It thrives very well under cultivation in the Redwood belt of California. It therefore seems reasonable that *Taxodium* might have been an element in the humid Redwood or Redwood border forest of past times along with other species now found associated with it.

The evidence for *Glyptostrobus* is much more remote, but does not fall in the realm of the impossible. When one considers the presence of *Ginkgo* associated with taxodiaceous leaves in the Mascall flora of Oregon it is not difficult to ascribe *Glyptostrobus* to the same flora. However, the balance of the ecological evidence, together with the general aspect of the twigs, lends support to the conclusion that the plants are largely referable to *Sequoia* with the exception of a few in the Mascall and related floras which I would refer to *Taxodium*.

### Genus SEQUOIA

The genus *Sequoia* is at present represented by two species. One of these, the Redwood (*S. sempervirens*), is restricted to what is known as the "Fogbelt" of the

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[1] F. E. Clements, Dev. Struct. Vegetation, 1904.

[2] R. W. Chaney, Quant. Stud. Bridge Creek Flora, Am. Jour. Sci. 8, 131, 1924. R. W. Chaney, Comparative Study Bridge Creek and Modern Redwood Forest, Carnegie Inst. Wash. Pub. No. 349, I, 1925.

[3] R. W. Chaney, Mascall Flora, Carnegie Inst. Wash. Pub. 349, II, 1925.

[4] W. S. Cooper, Broad Sclerophyll Vegetation of California, Carnegie Inst. Wash. Pub. 319, 1922.

Pacific Coast and extends from extreme southwestern Oregon to the vicinity of the Sur River in Monterey County, California. Nowhere does it occur further than 30 miles from the coast. The other species, the Big Tree (*S. gigantea*), occurs in quite a different habitat on the west slope of the Sierra Nevada Mountains of California. It extends from Placer County 250 miles southward to Tulare County and has an altitudinal range of from 5,000 to 8,000 feet. It is of interest to note that reproduction in the Redwood is largely by sprouting from old stumps as well as by seed—seed reproduction being most abundant in the north of its range. The Bigtree does not reproduce by sprouting, and seed reproduction is most abundant in the south of the range. These facts, doubtless, have some relation to the slight differences in climate at the two extremes of the range and might offer suggestions as to the migration of species.

Fossil records of the genus *Sequoia* go back to Jurassic times, but they attained their maximum development during the Oligocene, when they practically covered the Northern hemisphere. Since the Miocene their decline has been rapid, until today they are virtually a curiosity shunted off in a small corner of the continent.

The fossil representative of *Sequoia sempervirens* is in all probability *S. langsdorfii* which is hardly separable from it. However, the modern species is represented in Pliocene and Pleistocene deposits in California where it is known chiefly from wood. Much of this is only slightly or not at all altered; some of it is silicified. Wood is very frequently reported, often at great depths, by well drillers throughout the state. It is difficult, however, to verify these reports, as most often no dependable record is kept concerning it.

### Sequoia sempervirens Endlicher

*S. sempervirens* Endl., .Syn. Conif. 198, 1847.

Silicified wood and leaf prints occur in the deposits of the Sonoma Group known as the "Petrified Forest" near Calistoga. They occur in tuff and tuff-breccia and have been exposed by excavation.

Carbonized and unaltered wood occurs in the Merced sandstones at Mussel Rock, San Francisco. Associated with it are cones of *Pinus radiata* and *Pseudotsuga taxifolia*. Slightly carbonized wood has also been taken from a tunnel excavation in the Berkeley Hills. The above localities are all of Pliocene age.

### Sequoia langsdorfii (Brong.) Heer

(Plate 5, figs. 4, 8)

*S. langsdorfii* (Brong.) Heer, Fl. Ter. Helv. vol. 1, 54, pl. 20, fig. 2, pl. 21, fig. 4, 1855.

Leaves spirally arranged on short twigs, decurrent and disposed in two ranks; those on fertile twigs often reduced to scales; cones globose 1 to 2 cm. long, scales peltate, spirally arranged. The twigs are seldom over 2 to 4 times as long as broad and often show rather large buds near the tips. In general the twigs are oblong in shape.

The species is abundant in Cenozoic deposits of the northwest and in all probability ranged from Alaska to the Dakotas, south to Texas and northwestward. It is very abundant in the Bridge Creek deposits of the John Day Basin, Oregon.

In most floras of the later Cenozoic its associates show marked relationships with the modern Redwood forest. It is with considerable misgiving that I retain it as distinct from the modern species.

*Occurrence*—Bridge Creek shales, Dugout Gulch, 2 miles northeast of Clarnos Ferry. Locality 3739 and 3741.

*Collection*—Univ. Calif. Pal. Bot. No. 144, Locality 3739, No. 150, Locality 3741.

### Sequoia gigantea Lindl.

The presence of a record of *Sequoia gigantea* is very obscure. I have seen nothing from the Cenozoic of the West that I would definitely refer to this species; however, there is no reason to doubt its antiquity. It is much more closely related to Mesozoic forms than is *S. sempervirens*. Its habitat is not favorable to an extensive fossil record. It is a member of the arid transition zone occurring where streams are rapid and deposition for the most part is not going on. It is to be looked for in lake deposits.

### Taxodium nevadensis Lesq.

(Plate 5, figs. 2, 5, 6)

*T. nevadensis* Lesq., U. S. Geol. Surv., Terr. Ann. Rept. 1873, 273.

Although *Taxodium* does not occur as a member of this forest association today, its presence in the association in past times is noteworthy. The material is represented by an abundance of leaves and some staminate inflorescence and cones. The leaves are much more slender than are those of *Sequoia* and their characteristic grouping on the ends of the twigs help to distinguish them. More important, however, are the staminate inflorescences. These are slender, 3 to 5 cm. long and contain the staminate strobili sessile on the rachis. Cone material is common. The cones range from 0.5 to 3 cm. in diameter, and are in general globose.

*Taxodium* was fairly abundant and widespread during Cenozoic times from Eocene to the Miocene when it appears to pass out. It is frequently associated with *Sequoia* and occasionally was the dominant forest cover. This latter condition prevailed at Elko, Nevada, during Miocene time almost to the exclusion of *Sequoia*. In the Mascall (Miocene) of Eastern Oregon it was common in a rather mixed association with other conifers and broad sclerophyll elements. To the north in Washington and western Canada it occurred in beds reported to be of Eocene age. Today it is found only in the southeastern United States and in Mexico.

Associated with it in the Miocene deposits studied are the typical redwood forest indicators such as *Alnus carpinoides*, *Corylus macquarrii*, *Umbellularia oregonensis* and *Sequoia langsdorfii*. There are also a considerable number of species that are not at present found associated in the Redwood forest. Among these are *Ginkgo adiantoides* *Carpinus grandis*, *Liquidamber pachyphyllum*, *Magnolia dayana*, *M. californica*, *Ulmus speciosa* and *Persea pseudocarolinensis*. Related forms of these genera are now found in the southeastern United States, Mexico and Eastern China.

*Occurrence*—Mascall formation, White Hills, John Day Basin, 13 miles east of Dayville, Oregon; Locality 3735.

*Collection*—Univ. of Calif. Coll. Pal. Bot. Nos. 140, 141, 142, Locality 3735.

## Family CUPRESSACEAE

The Cupressaceae are represented in the Pacific Coast flora by 5 genera and about 15 species. Of these only 5 species occur north of the Columbia River. The remainder are confined to southern Oregon and California. Fossil records of the family go back to the upper Cretaceous and the genera were well marked then. Cenozoic deposits contain representatives of all of these genera, of which the following have been seen by the writer.

### Genus LIBOCEDRUS

The genus *Libocedrus* is represented in North America by one species, *L. decurrens* of the West. It is confined to the southern half of the Pacific Coast coniferous forest, where it is widely distributed throughout the Sierras and Cascade Mountains of Southern Oregon and California and the coastal mountains of Northern California. It reaches the cross ranges of Southern California and extends southward to the San Pedro Martir of Lower California.

During Miocene time the genus was represented by 3 species in Western America: *L. coloradensis*, Ckl. from the Florissant beds of Colorado; *L. predecurrens* Knowlton from the Latah beds at Spokane, Washington; and the modern species was present in the Mascall beds of Oregon. Closer study of more material of these forms may result in their reduction to a single species, but from the material in hand such action is not at present warranted.

*L. coloradensis* Ckl. is represented by slender twigs that are closely branched and possessing slender leaves, whose tips spread from the twig. Its general aspect is that of a much more delicate and slender foliaged tree than the modern species.

*L. predecurrens* Knowlton on the other hand is a much coarser plant whose twigs are comparatively broader and whose scale-like leaves are somewhat rounded at their tips and hardly spreading from the twigs.

Fossil material of the modern species is herewith described.

### Libocedrus decurrens Torrey

(Plate 5, figs. 3, 7, 9, 10, 11)

*L. decurrens* Torr., Smithsonian Contribution, 6, 7, 1854.

Leaves scale-like in apparent whorls of 4, the opposite pairs unlike, leaf bases decurrent on stem; nodes 5 to 7 mm. long; cones with imbricated scales in decussate pairs, the outer pair much shorter than the next, inner pair fused. Cone 12 to 20 mm. long; seed 10 to 15 mm. long, wing notched on one side—morphologically 2 wings of unequal development.

The modern species is one of the 4 dominant species of the yellow pine belt of the Sierra Nevada Mountains of California and the Cascades of Oregon, the other three being *Pinus ponderosa*, *P. lambertiana* and *Abies concolor*. In the Coast Ranges it is also closely associated with *Pseutotsuga taxifolia* and Redwood border elements. In the Santa Lucia Mountains it is found in close proximity to *Abies venusta*. Broad-leaved associates are *Quercus chrysolepis*, *Q. kelloggii*, *Cornus nuttallii*, *Arbutus menzesii*, *Alnus rhombifolia* and *Umbellularia californica*.

The fossil species was associated with the Redwood border elements of the Mascall flora. These include *Sequoia langsdorfii*, *Abies chaneyi*, *Alnus carpinoides*, *Arbutus mathesii*, *Quercus convexa*, *Quercus pseudolyrata* and *Umbellularia oregonensis*.

*Occurrence*—White Hills, Mascall formation, 13 miles east of Dayville, John Day Basin, Oregon; Locality 3735.

*Collection*—Univ. Calif. Coll. Pal. Bot. Nos. 145, 146, 147, 148, 149.

## Genus THUYA

The genus *Thuya* is represented on the Pacific Coast by one species. It is common throughout the northern humid forest and extends into the North Coast Ranges of California where it is associated with the Redwood forest elements. A great bulk of fossil materials of North America has been referred to this genus and it ranges in occurrence from the Cretaceous to the Pleistocene.

### Thuya garmani Lesq.

*Thuya garmani Lesq.*, U. S. Geol. Surv., Terr. Ann. Rept. 1872, 372.

Lesquereux reports *Thuya garmani* from the Miocene at Elko, Nevada. Material not unlike it occurs in the Mascall deposits of Oregon. It is represented by a twig 3 to 4 cm. long whose scale leaves are in apparent whorls of 4 and relatively long. Arising from the axils of some of the lateral ones are short twigs with short, rounded scales, also arranged in apparent whorls of 4. The opposite pairs are unlike.

The material shows close resemblance to the modern *Thuya plicata* of the West and is perhaps its forerunner in the Miocene.

*Occurrence*—Mascall formation, White Hills, 13 miles east of Dayville, Oregon; Locality 3735; Elko, Nevada.

*Collection*—Univ. Calif. Coll. Pal. Bot., No. 153; Locality 3735.

### Genus CUPRESSUS

The genus *Cupressus* is of particular interest in the living forest on the Pacific slope. Five species are recognized, all of which are of scattered or isolated distribution and nowhere do they occur in very great abundance. They appear to belong to a relict flora that is finding the present climate unfavorable to its further extension. They are now making a final stand and will probably face an early extinction.

#### Cupressus macrocarpa Hartweg

(Plate 5, fig. 12)

Gard. Jour. Hort. Soc. London 4, 296.

*Cupressus macrocarpa* is an endemic species on the Monterey peninsula at the north end of the Santa Lucia Mountains. It is restricted to the coastal bluffs around Monterey Bay and never more than a few hundred yards from the sea. It seems almost without question to be a relict of the past, yet fossil evidence for its previous existence is far from convincing.

Penhallow[1] records wood from the Cretaceous and Tertiary of Canada which, through doubt as to its affinity, he terms *Cupressinoxylon macrocarpoides*. He refers it as being closely related to, if not the direct ancestor of, *Cupressus macrocarpa*.

Knowlton[2] records *C. macrocarpa* from the Pleistocene deposits at Rancho La Brea. The material is represented by a cone 35 mm. wide by 25 mm. long. The umbos are flattened.

It is difficult to definitely refer a cone to a species in this genus because of the range of variation of the species. It is open to question whether many of our cypresses are really more than varietally distinct from one another. Hence the reference of this cone to *C. macrocarpa* is open to question. It could well be referred to *C. quadalupensis* but is too large for reference to any other of the described forms of Western North America.

It probably belongs to wood that occurs with it in the pit at Rancho La Brea, but certainly does not belong to the species (*C. macnabiana*) to which this wood has been referred. *C. macnabiana* has the umbos of its cone scales produced to a cone-like horn.

*Occurrence*—Tar pits, Rancho La Brea, Los Angeles County, California; Locality, Pit 16.[3]

*Collections*—Los Angeles Museum Locality 16, No. A. 197, 194.

### Genus JUNIPERUS

The genus *Juniperus* is represented in the Pacific Coast forest by five species. Of these only *J. occidentalis* and *J. californica* are endemic to the flora. The remainder are of rather widespread distribution and belong properly to the Rocky Mountain flora or the Great Basin flora. The genus is very old, being represented in deposits as far back as Upper Cretaceous. There are doubtful records even earlier.

#### Juniperus californica Carr.

(Plate 5, fig. 1)

Rev. Hort. 1854, 352.

*Juniperus californica* is found in the Coast Ranges from Lake County, California, to the mountains of northern Lower California and in the western foothills of the southern Sierra Nevada Mountains. It is replaced in the Great Basin and in the Desert Mountains of the Southwest by *J. californica* var. *utahensis* which is treated as a distinct species by some authors.

---

[1] D. P. Penhallow, Rept. Tert. Pl. British Columbia Can. Dept. Mines Pub. No. 1013, 1908.

[2] Ref. *C. macrocarpa* Knowlton, Jour. Wash. Acad. Sci., vol. 6, 85, 1916.

[3] The cone was picked up on the dump of discarded débris from the excavations. Its exact location in Pit 16 is unknown.

A collection of seeds and wood referable to this species was found in the tar pits of Rancho La Brea. The seeds, judging from their size and shapes, occurred from 1 to 3 in a cone. Wood of the juniper is abundant in the deposit. A small twig of leaf material that is rather poorly preserved and whose leaves are arranged in decussately opposite pairs may be referred here or may possibly be referable to the genus *Cupressus*.

Penhallow records wood belonging to this species in the Pleistocene near Orleans, Humboldt County, California.

*Occurrence*—Tar pits, Rancho La Brea, Los Angeles, California; Locality, 184, 56, 58.

*Collections*—Los Angeles Museum. Locality Nos. 184, 56, 58.

## CONCLUSION

It has been pointed out that much of the above material occurs in deposits associated with Redwood forest or Redwood border forest elements. Indicators of these floras are:

Acer bolanderi
Alnus carpinoides
Arbutus mathesii
Corylus macquarrii
Quercus consimilis
Quercus convexa
Quercus pseudolyrata
Sequoia langsdorfii
Umbellularia oregonensis

Whenever a flora is dominated by any combination of these species it may be said to belong to the Redwood or the Redwood border forest.

To draw conclusions as to the interpretation of these data is hazardous. If we treat the flora as a whole we may conclude that it was much more widespread throughout Cenozoic time than now, and that at any particular locality one or more of the characteristic species may have been lacking or rare, so that its record has not been disclosed as yet. The present distribution of the flora can be roughly stated as in the California Coast Ranges from Point Conception to the Rogue River in Oregon. The past distribution in North America can be stated as covering much of the area from the Great Slave Lake in Canada south through the Rocky Mountains to Texas and westward (see map). There is also evidence for its occurrence in Manchuria and Siberia as well. However, this can not apply to any particular species. Some of them like *S. langsdorfii* and *Alnus carpinoides* were definitely widespread but evidence is lacking for any such statement for the other coniferous species and must await a time when it will be possible to study all the deposits that contain these materials. Coniferous material, other than *Sequoia*, is relatively rare.

There are indications that such a form as *Libocedrus coloradensis* was much more widespread than its modern equivalent, *L. decurrens*. *Ginkgo* was widespread and it is now extinct in North America. *Taxodium* was common, and is not now in the living forest. Evidence for the distribution of the species of *Pinus* does not warrant statements as to broad distribution. For the most part the known localities of their past distribution are limited to 1 or 2 or 3, hence we can do no more than infer from this that they were more widespread than now. The same is true of the other species dealt with.

When we consider the flora as a whole and compare it with the modern flora we are justified in assuming that the homogeneity of the composition of the component habitats had its counterpart in the fossil flora. We can expect then to find in the fossil Redwood forest only occasional other conifers such as *Torreya* or *Taxus*, while in the Redwood border forest we may expect *Sequoia*, varying in abundance, associated with a very large array of broad sclerophyll elements and scattered members of other coniferous groups such as Pines of the Closed Cone and Nut Pine groups and members of the Cupressaceae. This being the case, the relative lack of coniferous fossils is not surprising. This seeming lack of conifers in the fossil flora can also be accounted for by reason of their growing in habitats away from sites of deposition. For the most part, the modern forms, the pines and firs, represented in these floras grow on the drier slopes where erosion is the dominating process. Any that may reach the streams are most frequently destroyed before they reach a site of deposition. Chaney, in his deposition studies in Redwood Creek, Muir Woods National Monument, found no *Torreya* or *Pseudotsuga*. Both of these species occur rather commonly along the upper reaches of the streams and on the hills only a short distance above the sites studied, but their needles and cones were destroyed in transport from the point of their origin to the sites where deposition is going on. It is therefore probable that the percentage of coniferous individuals and perhaps even the percentage of coniferous species was much greater than the record shows.

In comparing the fossil species with Table 3 it will be noted that of the endemic species of conifers that are now found in the Klamath area, 6 are known from Cenozoic deposits. Of those in the Franciscan area, 8 are known from Cenozoic deposits. Of those in the Lucian area, 8 are known from the Cenozoic, while all of those now found in the Insular are also found in Cenozoic beds.

It is possible, then, to account for the presence of the endemic elements of the California Coast Range and parts of the Sierra-Cascade floras as being relicts from floras that were widespread over much of the western part of North America. But sources of the widespread elements of the Northern Humid forest and the Sierra-Cascade Forest are yet to be accounted for. They are to be looked for in deposits far to the northward.

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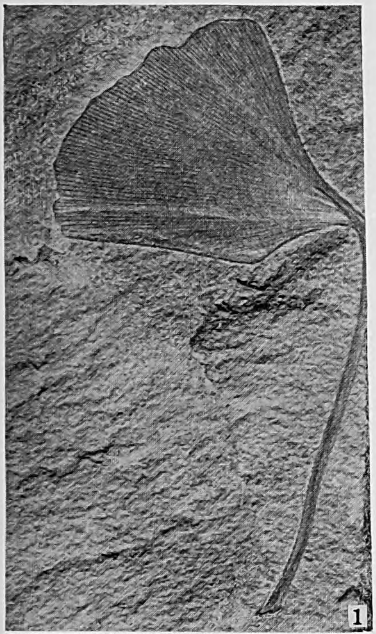

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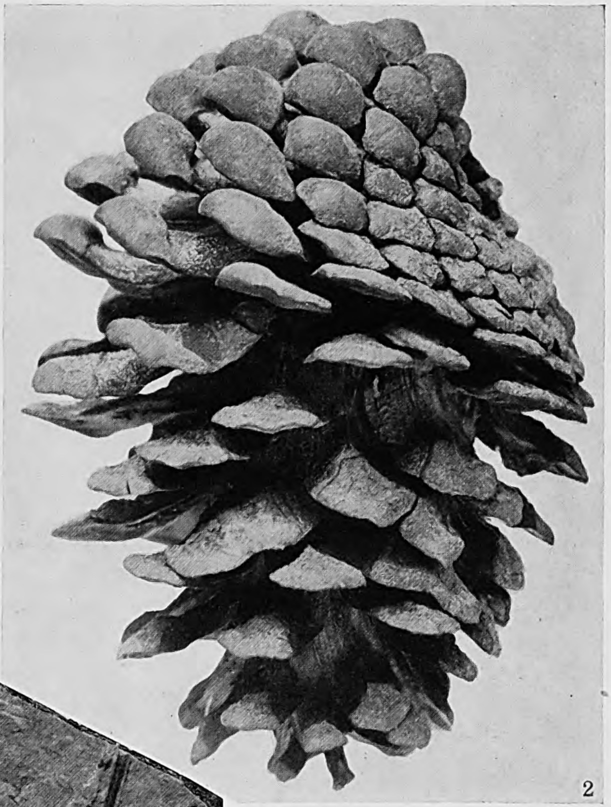

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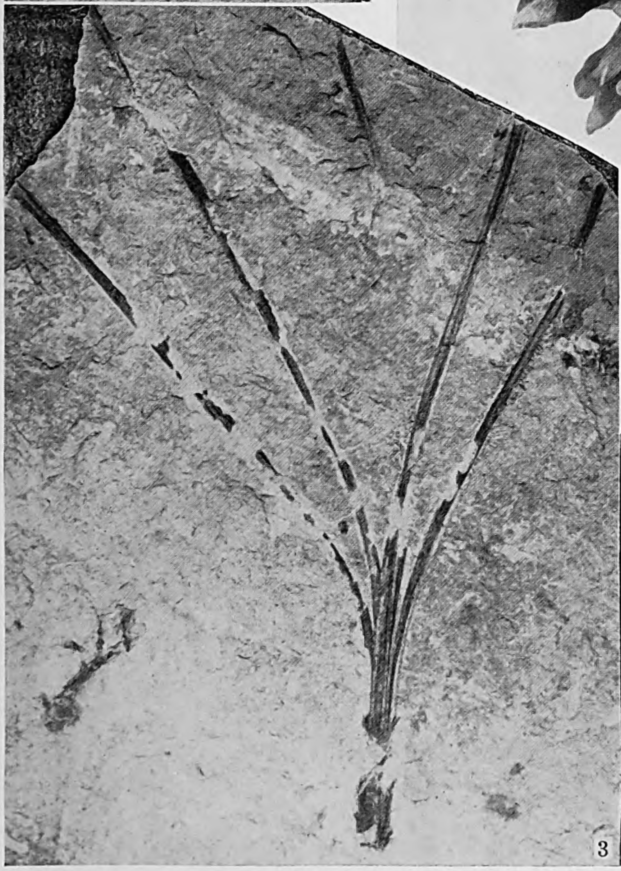

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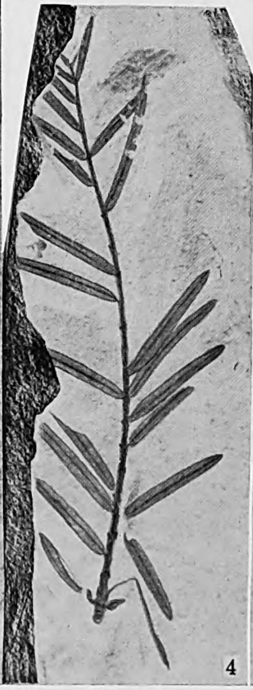

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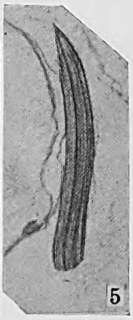

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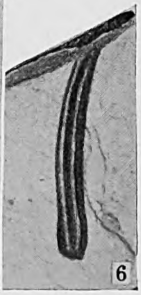

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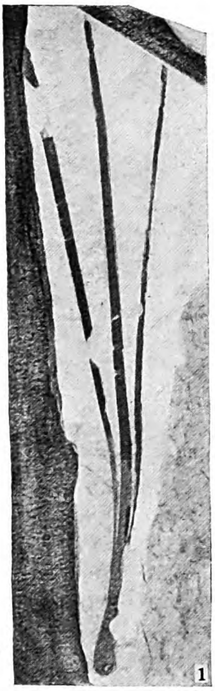

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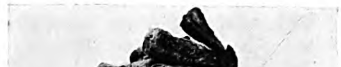

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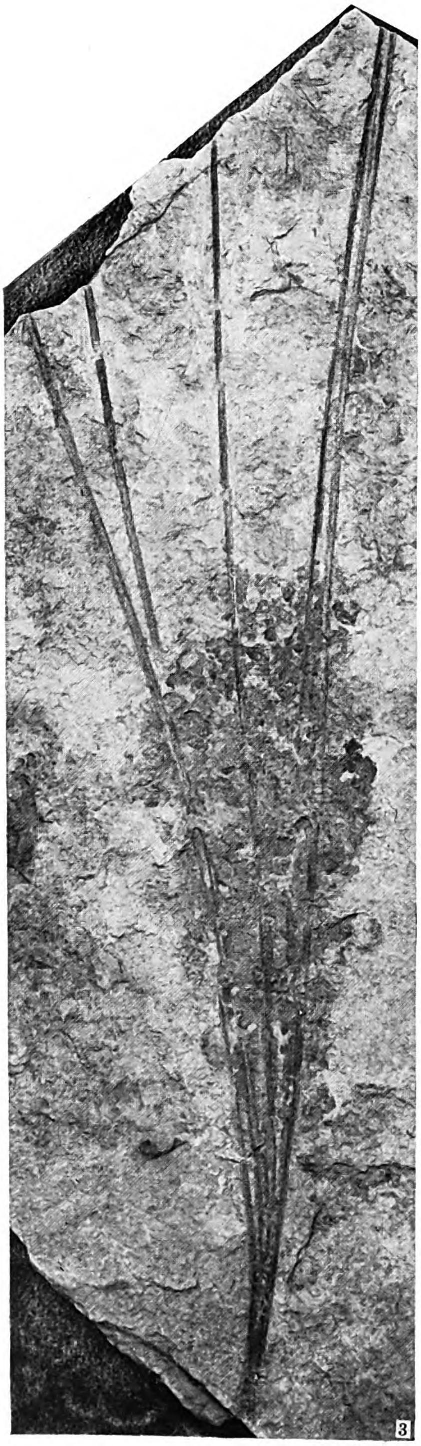

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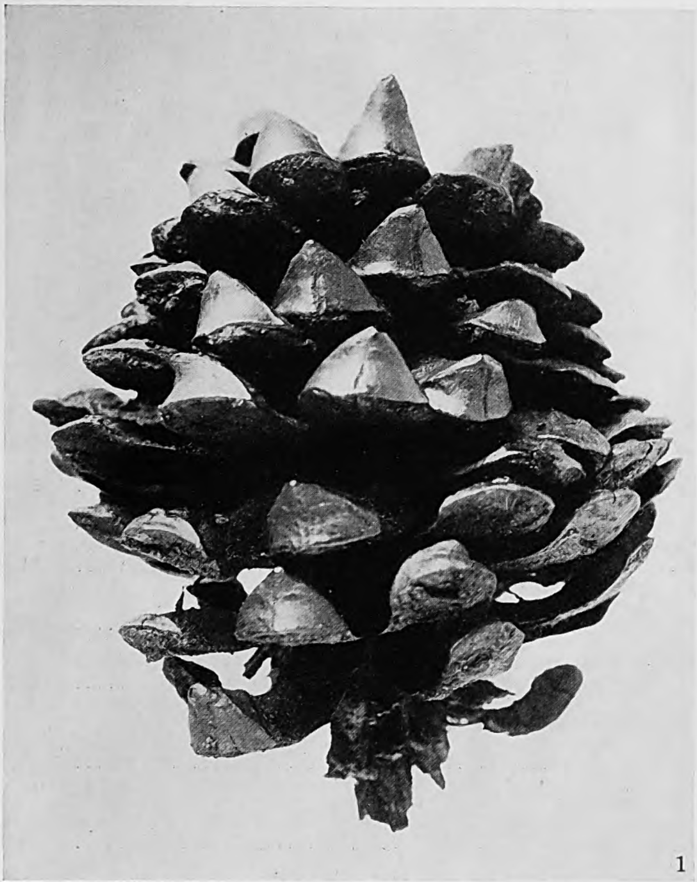
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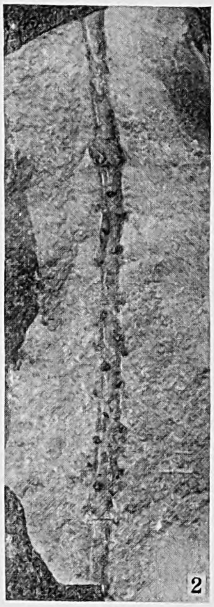
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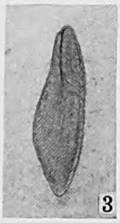
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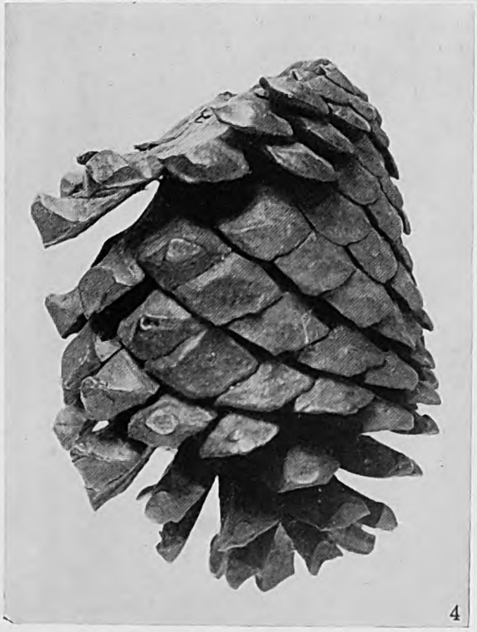
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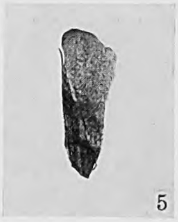
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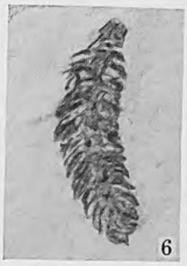
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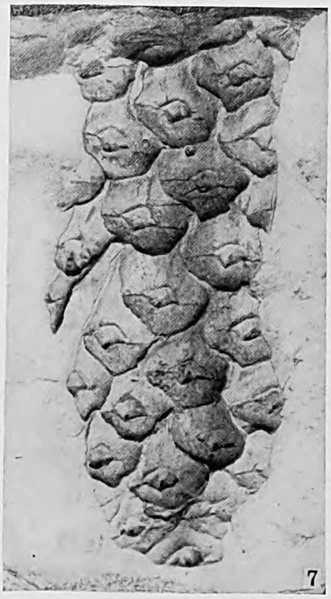
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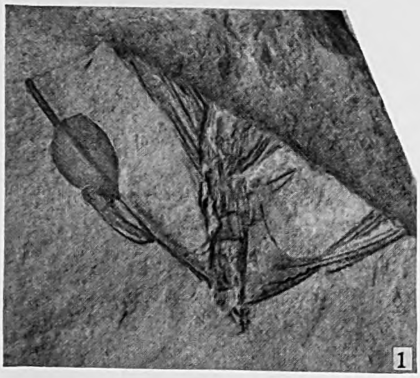

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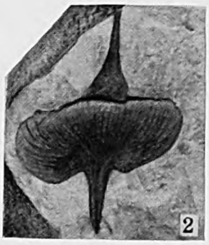

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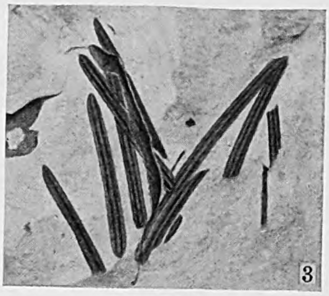

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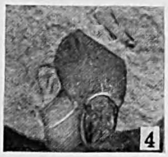

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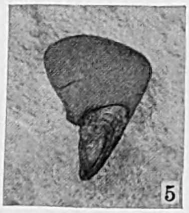

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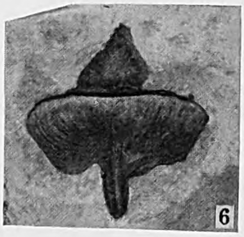

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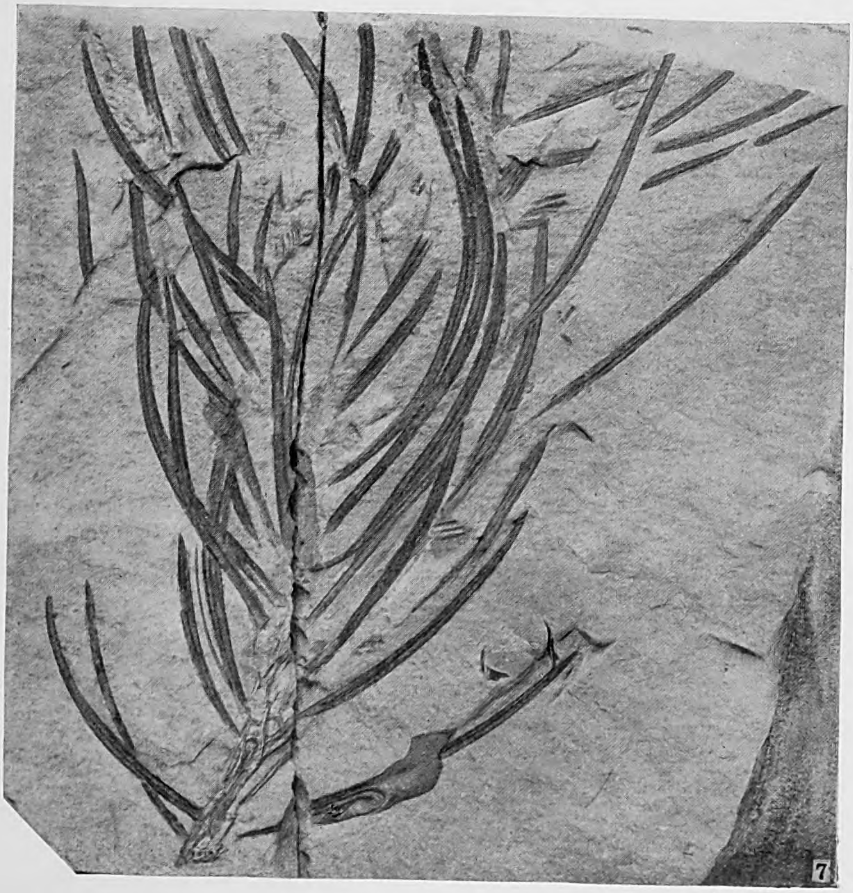

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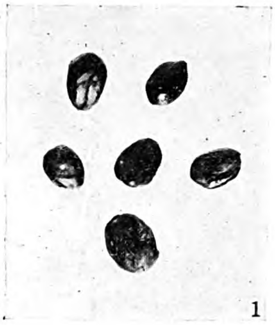
| FIG. 12—*Cupressus macrocarpa* Hartweg. Cone. × 1. Los Angeles Museum. Tar pits, Rancho La Brea, Los Angeles, California | 156 |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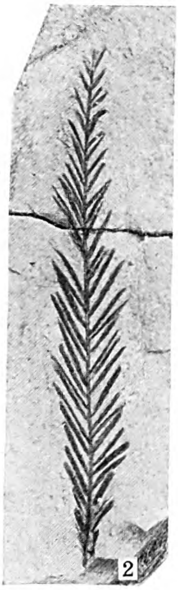
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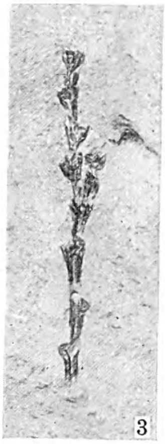
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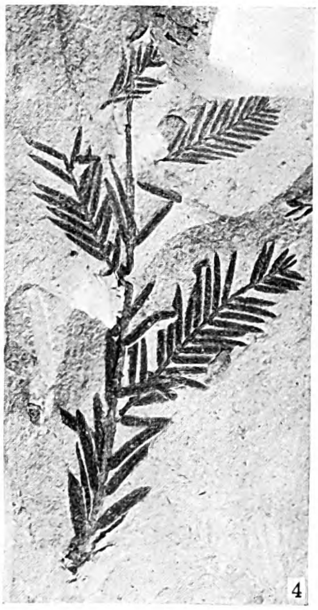
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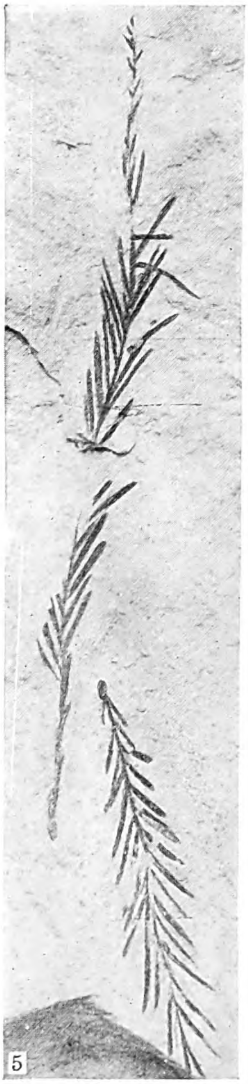
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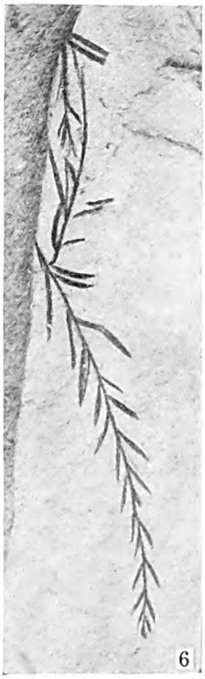
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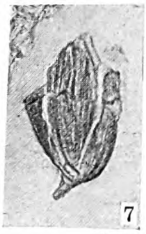
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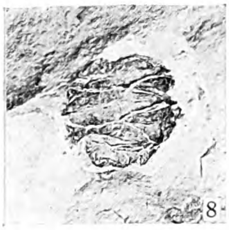
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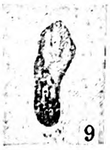
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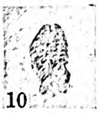
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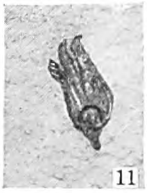
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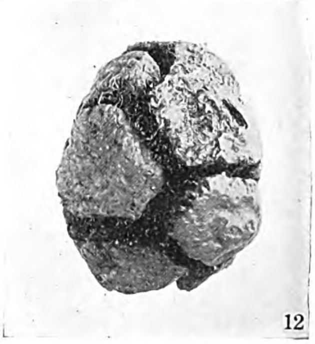
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